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# SUMMARIES OF SOLID WASTES RESEARCH AND TRAINING GRANTS - 1968

Louis W. Lefke

Consumer Protection and Environmental Health Service
Washington, D. C.

1968

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# Summaries of Solid Wastes Research and Training Grants - 1968

*Compiled by*

LOUIS W. LEFKE

*Sanitary Engineer*

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Consumer Protection and Environmental Health Service

ENVIRONMENTAL CONTROL ADMINISTRATION

***Solid Wastes Program***

CINCINNATI

1968

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Lefke, L. W., comp. *Synopses of solid wastes research and training grants 1967*. Public Health Service Publication No. 1599. Washington, U.S. Government Printing Office, 1968 48 p.

ABSTRACT: This publication is a new compilation of summaries of all research and training grants (both terminated and active) funded by the Solid Wastes Program of the U.S. Department of Health, Education, and Welfare. The compilation includes progress through December 31, 1967. The majority of the research has been underway for three years or less.

Since the characteristics of solid wastes are constantly changed by product innovations, industrial process modifications, consumer buying patterns, etc., the effort of the Solid Wastes Program is to develop efficient and economical management practices to meet the changing national needs. Thus, many solid wastes problems are being investigated by the Program. Some of these studies are carried out through research grants and include such areas as: bacterial contamination from hospital solid wastes; physical and chemical composition of municipal refuse; handling, treatment, and disposal of animal wastes; utilization of agricultural wastes; pipe transport of waster, and pyrolysis of wastes. A total of 53 research grants are summarized.

KEY WORDS

research
training
grants
literature
Solid Wastes Program
planning
personnel

The training grant program has as its objectives to develop qualified professional personnel in the solid wastes field in order to utilize the results of research. Institutions involved in the eight solid wastes training grants are presented, as well as a brief description of the respective programs. Research projects and training program directors are indexed.

Library of Congress no. 68-62136

LISTING OF

RESEARCH AND TRAINING GRANTS AWARDED

DURING THE PERIOD JANUARY 1 TO JULY 1, 1968

## Research Grants

### STUDIES OF MODIFICATIONS OF SOLID INDUSTRIAL WASTES

Dr. Cornelius S. Grove
Department of Engineering
Syracuse University
Syracuse, New York 13210

UI 00537-01A1
Initial year support: $46,419
Terminates: January 1971

### BIOLOGICAL CONVERSION OF ANIMAL WASTES TO NUTRIENTS

Dr. Byron F. Miller
Department of Poultry Science
Colorado State University
Fort Collins, Colorado 80521

UI 00551-01A2
Initial year support: $19,222
Terminates: May 1970

### STUDY OF INSTITUTIONAL SOLID WASTES

Prof. Jerry C. Burchinal
Department of Civil Engineering
West Virginia University
Morgantown, West Virginia 26506

UI 00554-01
Initial year support: $55,995
Terminates: March 1970

### POULTRY OFFAL SILAGE AS A FEED INGREDIENT

Dr. Charles H. Hill
Department of Poultry Science
North Carolina State University
Raleigh, North Carolina 27607

UI 00560-01
Initial year support: $15,625
Terminates: May 1970

### ANIMAL WASTE COMPOSTING WITH CARBONACEOUS MATERIAL

Dr. Charles B. Davey
Department of Soil Science
North Carolina State University
Raleigh, North Carolina 27607

UI 00561-01
Initial year support: $33,467
Terminates: May 1971

EFFECTS OF PROCESSING POULTRY MANURE ON DISEASE AGEN

Dr. James R. Howes
Poultry Department
Texas A & M University
College Station, Texas 77843

UI 00872-01
Initial year support: $34,212
Terminates: May 1970

Training Grants

SOLID WASTES TECHNOLOGY FOR URBAN AREAS

Dr. H. Nugent Myrick
Cullen College of Engineering
University of Houston
Houston, Texas 77004

UI 01022-01
Initial year support: $55,138
Terminates: June 1971

SOLID WASTES MANAGEMENT

Dr. Richard S. Engelbrecht
Department of Civil Engineering
University of Illinois
Urbana, Illinois 61801

UI 01066-01
Initial year support: $44,083
Terminates: June 1973

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## INTRODUCTION

THIS PUBLICATION is a compendium of solid wastes research and training grants supported by the Environmental Control Administration, Consumer Protection and Environmental Health Service, extending and updating through December 31, 1967, the previous issuance, PHS Publication No. 1596. The purpose of this review is to briefly inform interested readers of solid wastes research projects and training programs. It is hoped that the publication may stimulate some readers to conceive new approaches or modifications of existing practices which, through research and development, will lead to better methods of solid wastes treatment, reuse, and disposal from all national sectors—municipal, industrial, commercial and agricultural sources.

The current Solid Wastes Program was established in October 1965 under authority of the Solid Waste Disposal Act, Public Law 89-272. Prior to this Act, a modest solid wastes research grant effort was supported by the former Division of Environmental Engineering and Food Protection of the Public Health Service. Congress recognized the enormity of the solid wastes problem and the lack of extensive and concerted research, so that a portion of the Solid Waste Disposal Act is designed to fulfill this research need. Specifically, the Act authorized initiation and acceleration of a national research and development program for new and improved methods of proper and economic solid waste disposal, including studies directed toward the conservation of natural resources to reduce the amount of wastes and unsalvageable materials and to encourage the recovery and utilization of potential resources in solid wastes. The summaries presented in the following pages represent efforts to meet the research and training goals of the Solid Waste Disposal Act.

There is, probably, no single approach applicable to the wide array of solid wastes produced. Further, solid wastes characteristics are continually changing through product innovations, industrial process modifications, and general population living habit evolution. Solid wastes storage, collection, reuse, upgrading, and disposal practices have not kept pace with these changes.

The objective of the Solid Wastes Program is to develop efficient and economical solid waste management practices to meet the national needs. Extramural research is supported in practically all phases of the problem, for example, collection, disposal, reuse and health aspects. The majority of the supported research has been underway for three years or less; results, therefore, are just beginning to emerge from these efforts. Some solid wastes problem areas, e.g., industrial solid wastes, collection systems, and waste material reuse, have not received extensive research attention. It is hoped that pertinent, high quality research in these areas will be forthcoming.

The training grant program is an effort to develop personnel with advanced technical know-how and interest in solid wastes. Graduate-level training is offered to qualified students in solid wastes oriented programs. It is also the intent of the training program to produce professional workers in the solid wastes field who will be qualified to utilize the recommendations accruing from the research effort.

Other areas of support and assistance from the Solid Wastes Program, are (1) projects for demonstrating new and improved solid wastes technology with up

to two-thirds support; (2) studies and investigations of regional waste management systems, which also receive up to two-thirds support; (3) statewide solid wastes surveys and program planning with up to 50 percent support; (4) training, in addition to that supported by the training grant program, for administrative and operative solid wastes personnel; (5) technical services to supplement solid wastes management competencies at local and State levels; (6) intramural and contract research and development on problems of solid wastes; and (7) collection of solid wastes basic data and a system for retrieval.

—Richard D. Vaughan
*Chief, Solid Wastes Program.*

# SECTION I

## Terminated Solid Wastes

## Research Grants

## Bacterial Contamination from Hospital Solid Wastes

**Prof. Richard G. Bond**
**School of Public Health**
**University of Minnesota**
**Minneapolis, Minnesota 55455**

**Grant No. EF 00007–04**
**Final Year Support: $48,870**
**Grant Period: September 1, 1959–December 31, 1963**

OBJECTIVES: To study the microbial hazards involved in solid waste handling and associated housekeeping procedures in a representative cross section of hospitals.

APPROACH: Waste handling and resulting bacteriologic contamination were investigated at production areas, storage and utility areas, and at the site of ultimate disposal. The study included medical and surgical wastes, reusable instruments, laundry and kitchen wastes, and conventional solid wastes such as wastebasket trash. The techniques associated with waste handling were duplicated in a chamber where the microbiological environment was controlled. The quantitative and qualitative bacteriology associated with the particular method of solid waste handling was studied. Methods of minimizing environmental contamination investigated experimentally included three special areas: namely, linen chutes, corridor floor-cleaning procedures, and experimental animal surgery facilities.

Several methods suitable for tracing the generation and movement of bacterial contaminants were developed. Remedial measures were designed to reduce bacterial contamination from hospital solid wastes. Detailed information is available from the publications listed.

### PUBLICATIONS

GREENE, V. W., R. G. BOND, and G. S. MICHAELSEN. Air handling systems must be planned to reduce the spread of infection. *Modern Hospital*, 95(2):136, Aug. 1960.

GREENE, V. W., D. VESLEY, R. G. BOND, and G. S. MICHAELSEN. The engineer and infection control. *Hospitals (JAHA)*, 34(17):69, Sept. 1960.

GREENE, V. W., and L. G. HERMAN. Problems associated with surface sampling techniques and apparatus in the institutional environment. *Journal of Milk and Food Technology*, 24(8):262, Aug. 1961.

VESLEY, D., and M. BRASK. Environmental implications in the control of hospital-acquired infections. *Nursing Outlook*, 9(12):742, Dec. 1961.

GREENE, V. W., and D. VESLEY. Method for evaluating effectiveness of surgical masks. *Journal of Bacteriology*, 83(3):663, Mar. 1962.

GREENE, V. W., D. VESLEY, and K. M. KEENAN. New method for microbiological sampling of surfaces. *Journal of Bacteriology*, 84(1):188, July 1962.

GREENE, V. W., D. VESLEY, R. G. BOND, and G. S. MICHAELSEN. Microbiological contamination of hospital air. I. Quantitative studies. *Applied Microbiology*, 10(6):561, Nov. 1962.

GREENE, V. W., D. VESLEY, R. G. BOND, and G. S. MICHAELSEN. Microbiological contamination of hospital air. II. Qualitative studies. *Applied Microbiology*, 10(6):567, Nov. 1962.

MICHAELSEN, G. S., and D. VESLEY. Industrial clean room versus hospital operating rooms. *Air Engineering*, 5(9):24, Sept. 1963.

MICHAELSEN, G. S. Waste handling. In *Proceedings, National Conference on Institutionally Acquired Infections*, Minneapolis, Minnesota, Sept. 4–6, 1963. Public Health Service Publication No. 1188. Washington, D.C., U.S. Government Printing Office, 1964. p. 65.

VESLEY, D. Surface sampling techniques for the institutional environment—present status. In *Proceedings, National Conference on Institutionally Acquired Infections*, Minneapolis, Minnesota, Sept. 4–6, 1963. Public Health Service Publication No. 1188. Washington, D.C., U.S. Government Printing Office, 1964. p. 101.

VESLEY, D., and G. S. MICHAELSEN. Application of a sampling technique to the evaluation of bacteriological effectiveness of certain hospital housekeeping procedures. *Health Laboratory Science*, 1(2): 107, Apr. 1964.

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BULLOCK, W. E., J. W. HALL, W. W. SPINK, L. J. DAMSKY, V. W. GREENE, D. VESLEY, and H. BAUER. A staphylococcal isolation service: epidemiologic and clinical studies over one year. *Annals of Internal Medicine*, 60 (5):777, May 1964.

MICHAELSEN, G. S., and D. VESLEY. Dissemination of airborne microorganisms in an institutional environment. In *Surface Contamination; Proceedings, Symposium*, Gatlinburg, Tennessee, June 1964. B. R. FISH, *ed.* Oxford, Pergamon Press, [1967]. p. 285.

VESLEY, D., and G. S. MICHAELSEN. A technique for measurement of microbial contamination on flat surfaces. In *Surface Contamination; Proceedings, Symposium*, Gatlinburg, Tennessee, June 1964. B. R. FISH, *ed.* Oxford, Pergamon Press, [1967]. p. 321.

## Garbage and Wastes for Mushroom Production

**Dr. Seymour S. Block**
**Department of Chemical Engineering**
**University of Florida**
**Gainesville, Florida 32601**

**Grant No. EF 00085–05**
**Final Year Support: $17,940**
**Grant Period: January 1, 1959–December 31, 1964**

OBJECTIVES: To investigate the production of composts from municipal and industrial wastes capable of yielding mushrooms for human consumption, producing protein and vitamin-rich fungus mycelium for animal feed.

APPROACH: The work demonstrated that when properly blended, fortified, and composted, these waste materials supported mushroom growth and produced mushrooms in good yield and flavor. Analysis of the spent residue, composed largely of mushroom mycelium, showed it to contain over 15 percent nitrogen. The residue was shown to have potential as a feed ingredient for ruminant animals. The following publications contain detailed results gained from this research project.

PUBLICATIONS

BLOCK, S. S. Developments in the production of mushroom mycelium in submerged liquid culture. *Journal of Biochemical and Microbiological Technology and Engineering*, 2(3):243, Sept. 1960.

RAO, S. N., and S. S. BLOCK. Experiments in small-scale composting. *Developments in Industrial Microbiology*, 3:326, 1962.

BLOCK, S. S., and S. N. RAO. Sawdust compost for mushroom growing. *Mushroom Science*, 5:134, 1962.

BLOCK, S. S. Effect of casing soils on the shape of the mushrooms. *Mushroom Science*, 5:321, 1962.

AMMERMAN, C. B., and S. S. BLOCK. Feed from wastes: feeding value of rations containing sewage sludge and oakwood sawdust. *Journal of Agricultural and Food Chemistry*, 12(6):539, Nov.–Dec. 1964.

BLOCK, S. S. Composting conversion of solid wastes for mushroom growing. *Biotechnology and Bioengineering*, 6(4):403, Dec. 1964.

BLOCK, S. S. Garbage composting for mushroom production. *Applied Microbiology*, 13(1):5, Jan. 1965.

BLOCK, S. S., and S. N. RAO. Small-scale composting for mushroom growing studies. *Developments in Industrial Microbiology*, 6:284, 1965.

## The Physical and Chemical Composition of Municipal Refuse

**Prof. D. E. Bloodgood**
**Department of Civil Engineering**
**Purdue University**
**Lafayette, Indiana 47907**

**Grant No. EF 00146–05**
**Final Year Support: $13,800**
**Grant Period: September 1, 1957–December 31, 1962**

OBJECTIVES: To develop methods of sampling and analyzing municipal refuse.

APPROACH: Field studies were conducted in 7 major midwestern cities in order to obtain sam-

ples of refuse for laboratory analysis as well as to estimate the accuracy of the method used in obtaining these samples. It was found that sample areas constituting only 0.06 percent of the population of a city the size of Milwaukee could be used to estimate within 7 percent the quantity of refuse production from the entire city.

Laboratory studies were conducted in order to determine the error due to two necessary stages of sampling the collected refuse prior to chemical analyses. Laboratory studies also included the development of reliable methods for determining the following tests on municipal refuse: moisture, lipids, carbon, nitrogen, $K_2O$, $P_2O_5$, sulfur, and calorific value.

Results indicated significant differences in both quantity and quality of refuse produced in medium, high, and low socioeconomic areas of a city.

### Publications


Bell, J. M. The physical and chemical composition of municipal refuse. *The APWA Reporter*, 29(1):11, Jan. 1962.

Etzel, J. E., and J. M. Bell. Methods of sampling and analyzing refuse. *The APWA Reporter*, 29(11):2, Nov. 1962.

Bell, J. M. Characteristics of municipal refuse. In *Proceedings, National Conference on Solid Waste Research*, Chicago, Dec. 1963, University of Chicago Center for Continuing Education. Special Report No. 29. American Public Works Association, 1964, p. 28.


## Sanitary Engineering Applied to Livestock Manures


**Dr. Samuel A. Hart**
**Department of Agricultural Engineering**
**University of California**
**Davis, California 95616**



**Grant No. EF 00265–04**
**Final Year Support: $14,400**
**Grant Period: September 1, 1961–August 31, 1965**


Objectives: To develop sanitary and effective methods of managing the manure produced on concentrated livestock farms, such as dairies, beef feed lots, and poultry farms. To develop means of collecting manure from where it is defecated by the animals through improved methods and machinery.

Approach: Extensive laboratory and pilot plant operations of various processing and stabilization techniques—such as solids digestion, activated sluge, algae ponds, excess activated sludge composting, and drying were conducted to develop methods feasible at the farm level. Final disposal techniques and outlets were evaluated. These ideas were studied with the thought that the most probable disposal would be on agricultural land, where it must compete with inorganic fertilizers. The references cited contain detailed information on the research project findings.

### Publications


Hart, S. A. Digestion tests of livestock wastes. *Journal of Water Pollution Control Federation*, 35(6): 748, June 1963.

Hart, S. A. Fowl fecal facts. *World's Poultry Science Journal*, 19(4):262, Oct.-Dec. 1963.

Ostrander, C. E., and S. A. Hart. Degradation of manure collected in water under chickens. *Poultry Science*, 43(5):1144, Sept. 1964.

Hart, S. A. Thin spreading of slurried manures. *Transactions American Society of Agricultural Engineers*, 7(1):22, 1964.

Hart, S. A., and W. C. Fairbank. Disposal of perished poultry. In *Proceedings, Second National Symposium on Poultry Industry Waste Management*, Lincoln, May 19–20, 1964, University of Nebraska Center for Continuing Education. p. 213.

Hart, S. A., and M. E. Turner. Poultry manure lagoons. Paper presented at Second National Symposium on Poultry Industry Waste Management, Lincoln, May 19–20, 1964, University of Nebraska Center for Continuing Education.

Hart, S. A., and M. E. Turner. Lagoons for live stock manure. *Journal of Water Pollution Control Federation*, 37(11): 1578, Nov. 1965.

HART, S. A., and C. G. GOLUEKE. Producing algae in lagoons. *Transactions of the American Society of Agricultural Engineers*, 8:122, Nov. 1965.

HART, S. A., and M. E. TURNER. The design of waste stabilization ponds for the treatment of agricultural wastes. Paper presented at lecture series on Advances in Water Quality Improvement, Austin, Apr. 4–7, 1966. The University of Texas.

HART, S. A., J. A. MOORE, and W. F. HALE. Pumping manure slurries. In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366. St. Joseph, Mich., American Society of Agricultural Engineers. p. 34.

## National Conference on Solid Waste Research

**Dr. Ross E. McKinney**
**Department of Civil Engineering**
**University of Kansas**
**Lawrence, Kansas 66044**

**Grant No. EF 00549–01**
**Support: $18,478**
**Grant Period: July 1, 1963–June 30, 1964**

THESE FUNDS supported, in part, a national conference on solid waste to stimulate research in this field. Recognition was given to the long-range aspects of the solid waste disposal problem and the urgency of working toward a solution. The conference, held for two and one-half days in December, 1963, in Chicago, reviewed the problem of solid wastes in the United States. Some 36 papers and summaries were presented by authorities in the field.

The conference covered research needs in waste characterization, waste collection and transportation, and waste treatment and utilization. Efforts were directed toward encouraging young researchers to meet the research needs in this field.

The budget covered mainly travel and per diem expenses for program participants and Study Section members. Travel for 30 young researchers, travel for 3 foreign scientists, preparation and printing of the program, stenotype recording, transcription and publication of the proceedings was also funded.

### PUBLICATIONS

*Proceedings, National Conference on Solid Waste Research*, Chicago, Dec. 1963, University of Chicago Center for Continuing Education. Special Report No. 29. American Public Works Association, 1964. 228 p.

## Incineration of Infectious and Radioactive Solid Waste

**Dr. Leslie Silverman**
**Department of Industrial Hygiene**
**Harvard School of Public Health**
**Boston, Massachusetts 02115**

**Grant No. EF 00579–01 and 01S1**
**Final Year Support: $52,122**
**Grant Period: February 1, 1964–June 30, 1965**

OBJECTIVES: To investigate and analyze the performance characteristics of a new institutional incinerator-boiler facility designed to dispose of combustible, infectious and low-level radioactive biological solid wastes from research laboratories and hospitals.

APPROACH: The Harvard University incinerator–boiler was utilized to investigate its use for disposal of solid wastes from research operation and hospitals. Further studies were done on low-level radioactive solid waste incineration. Decontamination was evaluated.

## Sanitary Landfill Investigation

**Prof. Jerry C. Burchinal**
**Department of Civil Engineering**
**West Virginia University**
**Morgantown, West Virginia 26506**

**Grant No. SW 00038–03**
**Final Year Support: $29,374**
**Grant Period: June 1, 1962–May 31, 1966**

OBJECTIVES: To identity the groups of microorganisms active in refuse decomposition. To study oxidation conditions of buried refuse and the effects of moisture, temperature, nitrogen, phosphorous, and potassium on refuse decomposition. To investigate gas production and its composition. To obtain basic chemical and bacteriologic data concerning water pollution near landfills.

APPROACH: To accomplish these objectives, fresh household refuse and material retrieved from landfills were studied in parallel. In addition, the effects of different strip-mine spoils on refuse, either mixed or in layers, were evaluated. Generally these were laboratory investigations under controlled conditions, using various test cylinders for simulated landfills. In some cases, sampling pits were constructed in operating landfills at Morgantown, along with observation and sampling wells.

The basic objectives were fulfilled and the details are available in the publications listed below.

### PUBLICATIONS

DOBSON, A. L., and H. A. WILSON. Refuse decomposition in strip-mine spoils. *Proceedings of the West Virginia Academy of Science*, 35(Series 64 No. 7–4):59, Jan. 1964.

DOBSON, A. L., H. A. WILSON, and J. C. BURCHINAL. Factors influencing decomposition in sanitary landfills. *Bacteriological Proceedings*, A77, 1965. (*Abstract*)

## Handling, Treatment, and Disposal of Animal Wastes

**Dr. Thamon E. Hazen**
**Agricultural Experiment Station**
**Iowa State University**
**Ames, Iowa 50010**

**Grant No. SW 00040–03**
**Final Year Support: $21,913**
**Grant Period: June 1, 1963–May 31, 1966**

OBJECTIVES: To determine the physical, chemical and bacteriologic properties of hog wastes and the testing of methods for the management, treatment and disposal of these wastes in order to reduce any health hazards of potential water pollution. Wastes from other farm animals were also to be studied but in less detail.

APPROACH: Lagoons and their resulting effluent with various loading rates of both liquid and solid wastes received greatest attention, although anaerobic digesters and an oxidation ditch were studied also. Properties of raw manures and treated effluents were evaluated for total and volatile solids, specific weight, BOD, COD, nitrogen, phosphorous, potash content, odor, pH, bacteriologic content, and toxic substances, as well as other characteristics.

Results of this project demonstrated that sedimentation coupled with anaerobic digestion is an effective preliminary treatment for swine wastes. Digestion may be by heated digesters or unheated lagoons. The digester or anaerobic lagoon effluent is unsuitable for discharge to a surface waterway. Several secondary aerobic treatment methods were determined to be capable of reducing the anaerobically treated effluent so that the liquid effluent could be discharged to streams, recharged to groundwater, or reused as a manure transport media.

### PUBLICATIONS

TAIGANIDES, E. P., E. R. BAUMANN, H. P. JOHNSON, a T. E. HAZEN. Anaerobic digestion of hog wastes. *Jour of Agricultural Engineering Research* (*London*), 8(4) 327, 1963.

TAIGANIDES, E. P., E. R. BAUMANN, and T. E. HAZEN. Sludge digestion of farm animal wastes. Journal Paper No. J-4661, Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1433. Published, *Compost Science*, 4(2): 26, Summer 1963.

TAIGANIDES, E. P. Agricultural solid wastes. In *Proceedings, National Conference on Solid Waste Research, Chicago*, Dec. 1963, University of Chicago Center for Continuing Education. Special Report No. 29. American Public Works Association, 1964. p. 39.

TAIGANIDES, E. P., T. E. HAZEN, E. R. BAUMANN, and H. P. JOHNSON. Properties and pumping characteristics of hog wastes. *Transactions of the American Society of Agricultural Engineers*, 7(2): 123, 1964.

TAIGANIDES, E. P., and T. E. HAZEN. Animal waste disposal practices and their influence on farm building design. Journal Paper No. J-4830, Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1443. 1964.

TAIGANIDES, E. P. Disposal of animal wastes. Journal Paper No. J-4876, Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1433. 1964.

TAIGANIDES, E. P. Theoretical considerations of anaerobic lagoons for poultry wastes. Journal Paper No. J-4889, Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1433, 1964. Published, *Proceedings, Second National Symposium on Poultry Industry Waste Management*, Lincoln, May 19–20, 1964, University of Nebraska Center for Continuing Education. p. 251.

TAIGANIDES, E. P., and T. E. HAZEN. Properties of farm animal excreta. *Transactions of the American Society of Agricultural Engineers*, 9(3): 374, 1966.

WILLRICH, T. L. Primary treatment of swine wastes by lagooning. In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP-0366. St. Joseph, Mich., American Society of Agricultural Engineers. p. 70.

WALLIZE, J. The story of a 'model'; swine in confinement. *Iowa Farm Science*, 22(1): 3, July 1967.

MINER, J. R., and T. E. HAZEN. Alternatives to oxidation ditches under slotted floors. In *Proceedings, Tenth National Pork Industry Conference*, Lincoln, Nebr., Nov. 9, 1967.

## National Conference on Solid Waste Management

**Dr. Samuel A. Hart**
**Department of Agricultural Engineering**
**University of California**
**Davis, California 95616**

**Grant No. SW 00037–01**
**Fiscal Year: 1966**
**Support: $24,069**
**Grant Period: July 1, 1965–December 31, 1966**

THESE FUNDS supported, in part, a national conference on the management of solid wastes. The conference, held April 4 to 5, 1966, at Davis, California, explored operations research and systems analysis as possible tools in improving the approach to the involved metropolitan problems of waste management.

Approximately 350 persons attended the meeting. Representatives from the U.S. Public Health Service, universities, industry, governmental agencies, and private institutions presented papers.

### PUBLICATIONS

*Solid Wastes Management; Proceedings, National Conference*, Davis Campus, April 4–5, 1966, University of California. 214 p.

## National Symposium on Animal Waste Management

**Dr. E. Paul Taiganides**
**Agricultural Engineering**
**Ohio State University Research Fdn.**
**Columbus, Ohio 43212**

**Grant No. SW 00026–01**
**Fiscal Year: 1966**
**Support: $6,500**
**Grant Period: April 1, 1966–March 31, 1967**

THESE FUNDS supported, in part, a national research conference on the management of farm solid wastes at the Michigan State University, May 5 to 7, 1966. The conference was designed to appraise present animal waste needs, and give direction to and stimulate research on problems in

the field.

Another objective was to provide a forum for teams of scientists, engineers, public health officials, and others to exchange knowledge on agricultural waste problems. Over three hundred attended the conference, including a number of scientists from foreign countries.

PUBLICATIONS:

*Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366. St. Joseph, Mich., American Society of Agricultural Engineers. 161 p.

TAIGANIDES, E. P. Waste problem recognized. *National Hog Farmer*, 11(7):22, July 1966.

TAIGANIDES, E. P. Symposium prologue. In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366. St. Joseph, Mich., American Society of Agricultural Engineers. p. 1.

SCHLEUSENER, P. E. Symposium epilogue. In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366. St. Joseph, Mich., American Society of Agricultural Engineers. p. 152.

TAIGANIDES, E. P. Farm-waste management in Europe and India. *Agricultural Engineering*, 48(12):710, Dec. 1967.

## Fly and Economic Evaluation of Urban Garbage Systems

**Mr. Dean H. Ecke**
**Vector Control Specialist**
**Santa Clara County Health Department**
**San Jose, California 95128**

**Grant No. UI 00690–01**
**Final Year Support: 1966**
**Support: $45,879**
**Grant Period: May 1, 1966– April 30, 1967**

OBJECTIVES: To compare entomologic and economic evaluations of once-a-week garbage can service; twice-a-week garbage can service; once-a-week pickup from suspended paper bag containers; and twice-a-week service with paper bag containers.

APPROACH: Four economically comparable residental areas of approximately 500 homes each were selected in the City of Santa Clara, California, an area for each of the 4 systems studied. Paper bag containers were installed in 2 of the areas and use of standard garbage cans were continued in the other 2 areas. Garbage service was altered so that both once- and twice-a-week service could be compared between areas for each system. The new pickup schedules were started about one month before the collection of data so that residents and the garbage company could become familiar with the new systems. Maggot traps were installed under 40 representative units in each area from which all migrating fly larvae were collected. Adult fly density was detected by using 20 standardized attraction stations in each of the 4 areas. The entomologic evaluation was determined from the combined adult and larval fly counts as they related to fly densities and fly problems during 8 weeks in August and September, 1966.

The economic evaluation was primarily a time and motion study which compared the various aspects of the pickup service between each of the four areas.

The study indicated that the frequency of collection was probably more important than the type of system or container used, and although there was a reduction in fly numbers from once-a-week paper over once-a-week cans, the reduction was not enough to suggest adequate fly control. Both of the twice-a-week systems showed substantial reduction in fly production but the twice-a-week can system would probably require considerable follow-up to achieve satisfactory control. Twice-a-week paper bags did achieve satisfactory fly control.

It was also found that up to 30 percent savings in manpower could be achieved by substituting paper bags for metal cans but that unless the collection system was actually engineered around the paper bag concept the saving in time would probably not be sufficient to pay for the additional cost of the bags.

In conclusion, it was found that: (1) Once-a-

week can containers produced excessive numbers of flies in about 67 percent of the units. Once-a-week paper containers had high production in about 25 percent of the containers, twice-a-week cans produced significant numbers of flies from approximately 10 percent of the containers and the twice-a-week paper system did not produce a significant number of green blow flies.

(2) Frequency of garbage service was an important control factor, since neither of the once-a-week systems achieved satisfactory control, whereas the twice-a-week systems did produce substantial control.

(3) Individual garbage containers are independent fly sources with little or no dependence or nearby sources as to their productivity.

(4) Twice-a-week garbage service to suspended paper bag containers could achieve control of green blow flies provided that the community would be willing to bear the increased costs of the paper sacks and that 100 percent of the residences were included in the service.

PUBLICATIONS:

ECKE, D. H., and D. D. LINSDALE. Fly and economic evaluation of urban refuse systems. I. Control of green blow flies (*Phaenicia*) by improved methods of residential refuse storage, and collection. *California Vector Views*, 14(4):19, Apr. 1967.

ROGERS, P. A. and G. L. BELLENGER. Fly and economic evaluation of urban refuse systems. II. Fly and economic analysis of paper bag containers. *California Vector Views*, 14(5):29, May 1967.

## Conference of Institute for Solid Wastes

**Mr. Robert D. Bugher**
**Executive Director**
**American Public Works Association**
**Chicago, Illinois 60600**

**Grant No. SW 00023–01**
**Fiscal Year: 1966**
**Support: $10,000**
**Grant Period: June 1, 1966–December 31, 1966**

THESE FUNDS supported, in part, the first annual meeting of the Institute for Solid Wastes of the American Public Works Association (APWA), held in Chicago, Illinois, September 10 to 15, 1966. The Institute was formed August 29, 1965, within the structure of the APWA. The meeting was held in conjunction with the Public Works Congress and Equipment Show.

The funds helped to defray expenses incurred by specially invited representatives of the International Association of Public Cleansing (INTAPUC), to establish an international relationship within the national framework. The participation of experts in the field of solid wastes from other countries enhanced the conference. The conference focused on research in solid wastes.

PUBLICATIONS

*Proceedings, First Annual Meeting of the Institute for Solid Wastes*. Chicago, Sept. 13–15, 1966. American Public Works Association. 78 p.

## SECTION II

## Active Solid Wastes

## Research Grants

292-903—68——3

## Special Studies of a Sanitary Landfill

**Prof. Robert C. Merz**
**Department of Civil Engineering**
**University of Southern California**
**Los Angeles, California 90007**

**Grant No. UI 00518–08**
**Fiscal Year: 1968**
**Support: $20,901**
**Project Renewal Initiated: January 1, 1966**

OBJECTIVES: To continue and to expand a program begun in 1960 for obtaining field information on the behavior of the sanitary landfill under varying conditions of construction and operation.

APPROACH: Under the current project, 3 instrumented landfills existing under semi-controlled field conditions are being utilized to study landfill performance. The cells are each about 50 ft square by 20 ft deep, and are located within a large landfill operated by the County Sanitation Districts of Los Angeles County. One cell has been constructed to permit forced aeration of the placed refuse. Two other conventional cells were constructed to study percolation of water applied for support of turf and as simulated rainfall for a temperature climated. A fourth cell is actually a 10,000-gallon underground storage tank (95 in. by 28 ft), of 0.25-inch A–36 steel, which was packed with refuse and then sealed in order that volumetric measurement of all gas produced during decomposition can be measured.

### PUBLICATIONS

MERZ, R. C., and R. STONE. Landfill settlement rates. *Public Works*, 93(9):103, Sept. 1962.

MERZ, R. C., and R. STONE. Gas production in a sanitary landfill. *Public Works*, 95(2):84, Feb. 1964.

MERZ, R. C., and R. STONE. Sanitary landfill behavior in an aerobic environment. *Public Works*, 97(1):67, Jan. 1966.

MERZ, R. C., and R. STONE. *Factors controlling utilization of sanitary landfill site;* final report to Department of Health, Education, and Welfare, National Institutes of Health, and United States Public Health Service, Jan. 1, 1964, to Dec. 31, 1965. Los Angeles, University of Southern California. (*Limited distribution*)

MERZ, R. C., and R. STONE. Progress report on study of percolation through a landfill. *Public Works*, 98(12):86, Dec. 1967.

## Integrated Control of the Housefly

**Dr. Richard C. Axtell**
**Department of Entomology**
**North Carolina State University**
**Raleigh, North Carolina 27607**

**Grant No. UI 00515–05**
**Fiscal Year: 1968**
**Support: $17,842**
**Project Initiated: September 1, 1963**

OBJECTIVES: To explore factors affecting the attractiveness of houseflies to various predacious, manure-inhabiting mites and to study the susceptibility of these mites to insecticides commonly used for houseflies.

APPROACH: Two specific studies will be conducted. In one study, mixed populations of manure mites are to be examined to determine if the combination of different species results in higher frequency of predation and phoresy. Further work will be carried out to isolate the pheromones present in manure and in houseflies responsible for the attraction of mites. Microsurgery techniques with a laser beam will be used to investigate in greater detail the role of certain sensory areas in the mite for attraction.

In the other study, laboratory tests have been completed for 16 compounds of the comparative toxicities of various insecticides for housefly larvae and predaceous mites. Fly control was generally poor while the mite population was de-

stroyed by most chemicals. Insecticide treatment of poultry manure is not a desirable practice for fly control. Additional insecticides will be screened for toxicity and promising compounds are undergoing field evaluation. Field experiments in poultry houses indicate that improved fly control can be obtained by promoting a stable manure ecosystem and using limited amounts of insecticides.

### Publications


Axtell, R. C. Phoretic relationships of some common manure-inhabiting Macrochelidae (Acarina: Mesostigmata) to the house fly. *Annals of the Entomological Society of America*, 57(5):584, Sept. 1964.

O'Donnell, A. E., and R. C. Axtell. Predation by *Fuscuropoda vegetans* (Acarina: Uropodidae) on the house fly (*Musca domestica*). *Annals of the Entomological Society of America*, 58(3):403, May 1965.

Farish, D. J., and R. C. Axtell. Sensory functions of the palps and first tarsi of *Macrocheles muscaedomesticae* (Acarina: Macrochelidae), a predator of the house fly. *Annals of the Entomological Society of Ameria*, 59(1):165, Jan. 1966.

Axtell, R. C. Comparative toxicities of insecticides to house fly larvae and *Macrocheles muscaedomesticae*, a mite predator of the house fly. *Journal of Economic Entomology*, 59(5):1128, Oct. 1966.


## Succession and Ecology of Diptera in Cattle Droppings


**Dr. John R. Anderson**
**Department of Entomology and Parasitology**
**University of California**
**Berkeley, California 94720**



**Grant No. UI 00525–05**
**Fiscal Year: 1968**
**Support: $15,250**
**Project Initiated: October 1, 1963**


Objectives: To study cattle droppings as ecological units and to examine the extent to which the inhabitant organisms contribute to the breakdown and recycling of individual droppings.

Approach: The cowpat habitat is being studied, under both undisturbed pasture and experimental conditions, to determine succession and density of various Diptera species that inhabit the droppings. The time, place and pasture habitat in which individual cowpats are dropped will be assessed to determine how these factors affect surface succession and the subsequent fauna developing in and emerging from such pats. Both naturally-dropped and experimentally-exposed pats of known sizes are being studied.

The interrelationships between fauna will be assessed by standardized sampling methods to determine the relationships between numbers and species of arthopods and the rate of cowpat degradation and recycling of nutrients, and the effects of natural enemies on such pests as horn and face flies. As the face fly, *Musca autumnalis*, is not yet present in California, another aim is to be in a position to observe and study the impact of an exotic species on the native fauna (or vice versa).

Extensive detailed results are described in the publications listed.

### Publications


Anderson, J. R. Recent developments in the control of some arthropods of public health and veterinary importance. Muscois flies. *Bulletin Entomological Society of America*, 12(3):342, 1966.

Anderson, J. R. Biological interrlationships between feces and flies. In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366, St. Joseph, Mich., American Society of Agricultural Engineers, p. 20.

Foster, W. A. Co-operation by male protection of ovipositing female in the Diptera. *Nature (London)*, 214 (5092):1035, June 1967.

Poorbaugh, J. H., J. R. Anderson, and J. F. Burger. The insect inhabitants of undisturbed cattle droppings in northern California. *California Vector Views*, 15(3), Mar. 1967.

Anderson, J. R., and J. H. Poorbaugh. A new livestock fly moves toward California. *California Agriculture*, Mar. 1967.

## Mathematical Simulation of Refuse Collection and Disposal Systems

**Dr. Abraham Charnes and Dr. J. E. Quon**
**Department of Applied Mathematics**
**Northwestern University**
**Evanston, Illinois 60201**

**Grant No. UI 00699–04**
**Fiscal Year: 1967**
**Support: $18,394**
**Project Initiated: September 1, 1962**

OBJECTIVES: The development and perfection of a mathematical model to simulate the municipal refuse collection and disposal problem. This model will enable the engineer–designer to predict the behavior of a wide variety of proposed designs quickly and accurately, and thus to predict an optimum solution based upon more complex criteria than it has previously been possible to evaluate.

APPROACH: Collection and analysis of refuse disposal unit operations cost data and the expected type and amount of pollution resulting from the various collection and disposal methods is made from literature sources. Additional data is obtained by communication and direct interview with responsible municipal authorities, public health workers, and consulting engineers. A mathematical simulation analysis of refuse collection and disposal systems will be developed along with writing a computer program capable of considering stochastic variations in the system parameters for the daily route method of refuse collection.

Initial computations served to delineate the relationships of the several performance parameters (overall collections efficiency, length of workday, etc.) to the characteristics of the system (average daily quantity of refuse, daily variability in the quantity of refuse, truck capacity, etc.).

A computer program has been completed and will be available to requestors.

PUBLICATIONS

WERSAN, S., R. EISEN, J. QUON, and A. CHARNES. Computer simulation of a refuse collection system. Systems Research Memorandum No. 101. Chicago, The Technological Institute, College of Arts and Sciences, Northwestern University, Apr. 1964. 31 p. (*Limited distribution*)

QUON, J. E., A. CHARNES, and S. J. WERSAN. Simulation and analyses of refuse collection systems. Proceedings, American Society of Civil Engineers, *Journal Sanitary Engineering Division*, 91(SA5):17, Oct. 1965.

## Composting Fruit and Vegetable Refuse

**Mr. Walter A. Mercer**
**National Canners Association**
**Western Research Laboratory**
**Berkeley, California 94710**

**Grant No. UI 00524–04**
**Fiscal Year: 1967**
**Support: $29,146**
**Project Initiated: April 1, 1963**

OBJECTIVES: To develop a rapid, aesthetically acceptable, reliable, and economic method of disposal for high-moisture solid refuse produced in harvesting and processing fruits and vegetables, through accelerated rates and aerobic composting.

APPROACH: Pilot studies are conducted using aeration bins in which mixtures of fruit and vegetable canning wastes are composted with dry, moisture-absorbing materials, such as redwood bark, straw, sawdust, rice hulls, coffee grounds, and final compost from the process. The effects of repeated additions of fresh waste on the compost process with intermittent or continuous forced aeration are also being investigated.

Using information obtained by these pilot bin studies, and parallel to them, are large-scale windrow composting studies. In most cases, the compost material is turned and mixed on a flexible schedule.

Bin and windrow studies have shown the following: ground fruit waste required a higher proportion of adsorbent, but under these conditions the time required for the completion of a compost cycle was reduced by 50 percent. Lags in the development of a desirable microflora and temperature was overcome by the addition of lime, if caused by a low pH of the initial compost mixture. The addition of nutrients, such as a nitrogen

source, stimulated microbial growth and resulted in acceleration of the compost cycle. Composted municipal refuse and rice hulls were to adsorbant materials which performed satisfactorily without modification. Shredded redwood bark failed to adequately absorb moisture and appeared to inhibit microbial growth because of its high tannin content. Evaporation during composting of fruit waste (85% moisture) and microbial conversion of sugar and acids to carbon dioxide and water resulted in a substantial reduction in the weight and volume of the finished compost. Air-dried compost could be recycled as the adsorbent for fresh waste. The weight and volume of the finished compost showed only slight increases when recycled several times. Offensive odors did not develop during the composting process nor was fly breeding observed.

Use of the first open windrows, having varied heights and volumes of rice hulls, indicated that the height of the mass was an important parameter for efficient composting. Frequent waste additions could be made without altering the microbial degradation of the waste. Thus, open windrows could not provide the height required for efficient composting, and it was necessary to contain the compost mixture between permanent walls. Forced aeration—injecting air up through the compost mass—was superior to strictly mechanical means of providing aerobic conditions. Without forced aeration, anaerobic pockets developed within the windrow. Thermophilic temperatures could be sustained throughout an operating season by applying waste every day. Waste could be added and the compost turned at 12-hour intervals, thereby increasing the quantity of waste stabilized within a given time. An automated means of turning the windrow mass was developed. A quarry rock and gravel removal machine was modified for the purpose of mixing, turning, and aerating the windrows.

In summary, from a technological standpoint it has been demonstrated that the compost process is a feasible method of stabilizing high-moisture solid wastes such as those resulting from the processing of fruits. Continuous thermophilic degradation of organic waste, sustained over an operating season, provides for the most efficient stabilization of wastes with a given volume of adsorbent material. Equipment required to carry out an automated compost process has been developed and evaluated. Precise cost figures for the operation of a full-scale unit are not yet available.

### Publications


Mercer, W. A., W. W. Rose, J. E. Chapman, A. M. Katsuyama, and F. Dwinnell, Jr. Aerobic composting fruit and vegetable refuse. *Compost Science*, 3(3):9, Autumn 1962.

Mercer, W. A. Industrial solid wastes; the problems of the food industry. In *Proceedings, National Conference on Solid Waste Research*, Chicago, Dec. 1963, University of Chicago Center for Continuing Education. Special Report No. 29. American Public Works Association, 1964. p. 51.

Rose, W. W., and W. A. Mercer. Composting fruit waste solids. In *Proceedings, Eleventh Pacific Northwest Industrial Waste Conference*, Corvallis, Oregon, May 9–10, 1963. Circular No. 29. Engineering Experiment Station, Oregon State University. p. 32.

Rose, W. W., A. M. Katsuyama, J. E. Chapman, V. Porter, S. Roseid, and W. A. Mercer. Composting fruit and vegetable refuse. *Compost Science*, 6(2):13, Summer 1965.

Rose, W. W., and W. A. Mercer. Treatment and disposal of potato wastes. In *Proceedings, International Symposium on Utilization and Disposal of Potato Wastes*, Fredericton, New Brunswick, Canada, May 24–27, 1965. p. 147.


## Pyrolysis of Municipal Refuse


**Mr. Elmer R. Kaiser**
**Department of Chemical Engineering**
**New York University**
**Bronx, New York 10453**



**Grant No. UI 00526–04**
**Fiscal Year: 1968**
**Support: $26,315**
**Project Initiated: September 1, 1963**


Objectives: To determine the nature and quantity of the volatile matter from the pyrolysis of refuse constituents.

Approach: Investigation is being made of the gasification of solid waste materials normally disposed of by incineration, landfill or open burning, and to determine the feasibility of producing a gaseous fuel suitable for firing in a boiler or for other uses. Results will show the possibilities for yields of gases and heat from refuse and the volume of the ultimate flue gas after the gas is burned. A first step will be to determine the vola-

tile content of specific waste materials by heating small quantities individually in a closed retort and condensing liquid products.

Data have been obtained on the characteristics of representative refuse and gaseous products obtained under controlled destructive distillation.

A pilot-scale continuous refuse gasifier has been built to devolatilize refuse and to burn out the fixed carbon remaining after the devolatilization stage. The ashes are removed continuously from the gasifier. On a large scale, the refuse inerts (bottles, tin cans, ash, etc.) would be removed from the gasifier, while only the hot, raw fuel gas from the process would enter power boilers for steam generation.

PUBLICATIONS


KAISER, E. R. Refuse composition and flue-gas analyses from municipal incinerators. In *Proceedings, 1964 National Incinerator Conference*, New York, May 18–20, 1964. American Society Mechanical Engineers. p. 35.

KAISER, E. R. Combustion and heat calculations for incinerators. In *Proceedings, 1964 National Incinerator Conference*, New York, May 18–20, 1964. American Society Mechanical Engineers. p. 81.

KAISER, E. R. Chemical analysis of refuse components. In *Proceedings, 1966 National Incinerator Conference*, New York, May 1–4, 1966. American Society of Mechanical Engineers. p. 84.

KAISER, E. R. Prospects for reducing particulate emissions from large incinerators. *Journal of Air Pollution Control Association*, 16(6):324, June 1966. (*Condensation*). (For complete paper write to: Senior Research Scientist, School of Engineering & Science, New York University.)


## Biological Consequences of Plant Residue Decomposition in Soil


**Dr. William C. Snyder**
**Department of Plant Pathology**
**University of California**
**Berkeley, California 94720**



**Grant No. UI 00558–04**
**Fiscal Year: 1968**
**Support: $45,462**
**Project Initiated: February 1, 1964**


OBJECTIVES: To investigate and determine the nature and action of phytotoxic substances released into soils during the process of plant residue degrad..tion. To assess the biological consequences arising from the decomposition products on succeeding crops and their diseases. To ascertain the relationships between decomposition and products and types of plants and environmental fatcors. To evaluate the role of degradation products in the survival of pathogens in soil and to determine the nutritional requirements for pathogenicity and the role of crop residues in providing such nutrients.

APPROACH: The plant organic residue sources are barley, rye, soybean, timothy, and other common plants all of which are known phytotoxin producers upon decomposition. Phytotoxins will be obtained by extractive procedures and isolation and identification attempted using chromotographic and chemical techniques. Phytotoxicity assays will be run at the analytical separation stages by seed germination and root elongation evaluation. After identification, plant evaluation studies will be made in nutrient culture and nonsterile soil growth conditions. The persistence and prevalence will be determined for the identical compounds in nature. Fusarium and Thielaviopsis organims are to be used to determine the effect of phytotoxins on their parasitic activity in laboratory and whole-plant greenhouse studies. Soybean and barley tissue at various stages of decomposition in natural soil under controlled conditions will be assayed for the appearance and duration of production of these compounds.

Plant residue decomposition products have been separated by various techniques and their effects assayed. The effects noted are: inhibition of spore germination and mycelial growth, stimulation of pathogenesis, seedling growth, spore germination, mycelial growth, and sclerotium formation. Phytotoxin growth conditions also result in higher levels of $CO_2$ in the soil. Substances selectively toxic to plant parasitic nematodes were extracted from rye residues. One extracted fraction was identified as *n*-butyric acid. Propionic

acid and isobutyric acid which gave similar results may also be present. Four phytotoxic compounds were identified in extracts of decomposing barley residues and were found to account for 60 percent of the total phytotoxicity of these extracts. The compounds are: benzoic acid, phenylacetic acid, phenylpropionic acid, and phenylbutyric acid. These compounds were also found in residues decomposing in nature. Benzoic acid and phenylacetic acid were also identified as major toxic components of decomposing residues of cotton, cowpea, and soybean. These compounds showed no stimulatory effects on resting propagules of *T. basicola* in soil, but increased the susceptibility of cotton to attack by *T. basicola*. Phenylpropionic acid in particular increased the severity of *T. basicola* root rot at concentrations as low as 50 ppm in soil. This is probably due to an effect on host cell permeability with a resultant increase in exudation.

### Publications


Patrick, Z. A., T. A. Toussoun, and L. W. Koch. Effect of crop-residue decomposition products on plant roots. In *Annual Review of Phytopathology*. v. 2. Palo Alto, Calif., Annual Reviews, Inc., 1964. p. 267.

Patrick, Z. A., T. A. Toussoun, and H. J. Thorpe. Germination of chlamydospores of *Thielaviopsis basicola*. *Phytopathology*, 55(4):466, Apr. 1965.

Patrick, Z. A., R. M. Sayre, and H. J. Thorpe. Nematocidal substances selective for plant-parasitic nematodes in extracts of decomposing rye. *Phytopathology*, 55(6):702, June 1965.

Sayre, R. M., and Z. A. Patrick. Selective toxicity of some volatile fatty acids to plant-parasitic nematodes. *Phytopathology*, 55(10): 1074, Oct. 1965. (*Abstract.*)

Linderman, R. G., and T. A. Toussoun. Behavior of chlamydospores and endoconidia of *Thielaviopsis basicola* in nonsterilized soil. *Phytopathology*, 57(7):729, July 1967.

Linderman, R. G., and T. A. Toussoun. Pathogenesis of *Thielaviopsis basicola*. *Phytopathology*, 57(10):1007, Oct. 1967. (*Abstract.*)

Linderman, R. G., and T. A. Toussoun. Predisposition to Thielaviopsis root rot by phytotoxins obtained from decomposing plant residues. *Phytopathology*, 57(8):819, Aug. 1967. (*Abstract.*)

Toussoun, T. A., A. R. Weinhold, R. G. Linderman, and Z. A. Patrick. Identification of phytotoxins obtained from plant residues decomposing in soil. *Phytopathology*, 57(8):834, Aug. 1967. (*Abstract.*)

Toussoun, T. A., A. R. Weinhold, R. G. Linderman, and Z. A. Patrick. Nature of phytotoxic substances produced during plant residue decomposition in soil. *Phytopathology*. In press.


## Incineration of Bulky Municipal Refuse


**Mr. Elmer R. Kaiser**
**Department of Chemical Engineering**
**New York University**
**Bronx, New York 10453**



**Grant No. UI 00517–04**
**Fiscal Year: 1967**
**Support: $34,171**
**Project Initiated: February 1, 1964**


Objectives: To investigate the fundamentals of incineration of refuse too large for conventional apparatus when burned in a controlled, refractory-lined furnace. To determine an optimum time for consumption along with minimum emission of smoke, fly ash and a noncombustible residue. To establish engineering design data for prototype units.

Approach: The procedure being used is to determine the physics and chemistry of controlled combustion during the burning of different types of bulky refuse. Temperatures of the solids and gases in the pile, of the exit flue gases and of strategic refractory surfaces are measured. In addition, gases are sampled, the rate of air supply is measured, dust in the flue gases are determined and density evaluations are made.

The project has established design factors such as: refuse composition and analysis, burning rates, temperature, air rates, smoke emission, and furnace capacity.

### Publications


Kaiser, E. R. The incineration of bulky refuse. In *Proceedings, 1966 National Incinerator Conference*, New York, May 1–4, 1966. American Society of Mechanical Engineers. p. 39.

## A Study of Farm Wastes

**Prof. Stanley A. Witzel**
**Agricultural Engineering**
**University of Wisconsin**
**Madison, Wisconsin 53706**

**Grant No. UI 00556–04**
**Fiscal Year: 1967**
**Support: $45,264**
**Project Initiated: June 1, 1964**

OBJECTIVES: To study farm wastes in a changing agriculture to determine quality, physical character, chemical and biological composition, and the effects of animal housing practices. To evaluate the economic value of farm wastes to agriculture, and any adverse effect such wastes may have on public health.

APPROACH: Wastes from dairy cows are collected periodically, weighed, and analyzed. Exploratory analyses of swine and poultry wastes are planned and bacteriologic characteristics of fresh wastes from ruminating animals, lagoon waste input, and lagoon microorganisms are to be investigated. These studies will include liquid manure wastes being held in below-ground storage tanks for removal to fields. In soils, farm wastes receiving different methods of treatment will be compared by direct field application for their value in stabilizing soil structure and for their contribution to the nutrition of field crops. Sources and amounts of pollution of surface and subsurface waters resulting from various animal waste management and farming practices are to be studied.

Physical, chemical, and biological waste characterization studies have been carried out on various farm animal wastes both in the raw state and at different treatment stages. Microbiological reduction and odor abatement in anaerobically stored waste are being studied. Plant growth response and the properties of waste contributing to plant response to fresh and treated animal wastes are being evaluated in laboratory studies and in greenhouse and field trials.

### PUBLICATIONS

WITZEL, S. A., E. MCCOY, and R. LEHNER. Chemical and biological reactions from lagoons used for cattle. *Transactions of the American Society of Agricultural Engineers*, 8(3):449, 1965.

WITZEL, S. A., E. MCCOY, L. B. POLKOWSKI, D. J. ATTOE, and M. S. NICHOLS. Physical, chemical and bacteriological properties of farm wastes (bovine species). In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366. St. Joseph, Mich., American Society of Agricultural Engineers, p. 10.

MCCOY, E. Lagooning of liquid manure (bovine)—bacteriological aspects. ASAE Paper No. 66–926B. Presented at American Society of Agricultural Engineers Winter Meeting, Chicago, December 8, 1966.

POLKOWSKI, L. B., L. C. GRAMMS, and S. A. WITZEL. Lagooning of liquid manure (bovine)—material balance and design aspects. ASAE Paper No. 66–926A. Presented at American Society of Agricultural Engineers Winter Meeting, Chicago, December 8, 1966.

WITZEL, S. A., O. J. ATTOE, and R. F. HENSLER. *In* Discussion. Manure storage, processing and pumping. D. J. GRIBBLE. ASAE Paper No. 67–926B. American Society of Agricultural Engineers Winter Meeting, Detroit, December 12–15, 1967.

## Microbiological Stabilization of Animal Wastes

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**Grant No. UI 00519–03**
**Fiscal Year: 1967**
**Support: $22,932**
**Project Initiated: June 1, 1964**

OBJECTIVES: To study the stabilization of livestock wastes by microbial means and to determine the physical, chemical and microbiological characteristics of these wastes and changes occuring to the point of stabilization. To obtain information which will provide engineers the design criteria for the kind and size of processing equipment needed to convert this material into a harmless and less unsanitary state.

APPROACH: Measured quantities of animal excreta are placed in a stainless steel digester tank. Stabilization of these materials is observed while

varying the oxygen supply, pH, temperature, and the amount of water. Studies of the microbial flora will also be made to improve the stabilization rate. The biochemical oxygen demand (BOD) will be determined at both the start and end of the biox process to give a measure of changes made and the degree of stabilization. The various gases produced, $CH_4$, $CO_2$, CO, $NH_3$, $H_2$, and $H_2S$, will be collected and measured.

It has been determined that anaerobic and aerobic microorganisms are necessary to reduce animal waste BOD to acceptable levels. Studies are underway to determine the organisms and their enzymes responsible for hydrogen sulfide and thio-alcohol production during animal waste treatment. Animal waste strength has been related to human wastes.

PUBLICATIONS


BULLERMAN, L. B., and E. C. BERRY. Use of cheese whey for vitamin $B_{12}$ production. I. Whey solids and yeast extract levels. *Applied Microbiology*, 14(3): 353, May 1966.

BERRY, E. C. and L. B. BULLERMAN. Use of cheese whey for vitamin $B_{12}$ production. II. Cobalt, precursor, and aeration levels. *Applied Microbiology*, 14(3): 356, May 1966.

BULLERMAN, L. B., and E. C. BERRY. Use of cheese whey for vitamin $B_{12}$ production. III. Growth studies and dry-weight activity. *Applied Microbiology*, 14(3): 358, May 1966.

BERRY, E. C. Requirements for microbial reduction of farm animal wastes. In *Management of Farm Animal Wastes; Proceedings, National Symposium on Animal Waste Management*, East Lansing, Michigan, May 5–7, 1966, Kellogg Center for Continuing Education, Michigan State University. ASAE Publication No. SP–0366. St. Joseph, Mich., American Society of Agricultural Engineers. p. 56.


## A Study of Incinerator Residue


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**Philadelphia, Pennsylvania 19104**



**Grant No. UI 00509–03**
**Fiscal Year: 1967**
**Support: $62,100**
**Project Initiated: January 1, 1965**


OBJECTIVES: To obtain data on the physical, chemical and biological characteristics of incinerator residue through a joint program involving the Drexel Institute of Technology and the City of Philadelphia, Department of Streets, Public Health and Water. To determine the relationships between incinerator design, operation, input composition and incinerator residue. To ascertain, by biological observation, the fly and rat attraction and breeding about incinerator residue. To investigate the properties and usefulness of the residue as fill material. To determine the effect and result of tidal surging on residue fill for leaching contaminate water pollution and determination of the time-release mechanism.

APPROACH: Residue from two different types of Philadelphia incinerators (traveling and stationary grate) is analyzed for physicochemical characteristics and variance. Chemical and physical properties such as, hydrocarbon and water soluble fractions, nitrogen, potassium, ignition residue, particle size and heavy metals are assayed. Residue is to be classified in relation to potential for dust, odor, fly breeding, rat attraction, etc. Residue observations will be made in uncovered field deposits and the laboratory. All observations will be related to incinerator input properties and operation. Additional studies are to be undertaken to examine incinerator residue from unsegregated refuse input in other cities and other types of incinerators. Residue will be placed in an area subject to tidal surging to determine leaching and resultant surface water pollution as well as the contaminate time-release mechanism. In addition, laboratory lysimeter studies are to be made to evaluate contaminate leaching on a controlled basis.

A sampling system has been perfected and a routine formulated which yields a fairly homogeneous sample for chemical analyses. A list of chemical analyses for the identification of incinerator residue constituents has been established. The chemical analyses results indicate a significant difference between residues obtained from different incinerator designs, i.e., batch feed and traveling grate-continuous feed incinerators. It has been shown that traveling grate incinerator



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residue placed in the field attracts flies and other insects, and under appropriate moisture conditions allows breeding of these public health nuisances. Residue odors have been found to be a problem and are relatable to the putrefactive fraction present.

Placement of residue in a zone of saturated groundwater may have limitations imposed by the inorganic and organic components. Such residue deposition is a complex situation which requires evaluation of residue composition, and site geology, hydrology.

PUBLICATIONS

PURDOM, P. W. Characteristics of incinerator residue. In *Proceedings, First Annual Meeting of the Institute for Solid Wastes,* Chicago, Sept. 13–15, 1966. American Public Works Association. p. 38.

SCHOENBERGER, R. J., N. M. TRIEFF, and P. W. PURDOM. Special techniques for analyzing raw refuse or incinerator residue. In *Proceedings, 1968 National Incinerator Conference,* New York, May 5–8, 1968. Submitted for presentation and publication. American Society of Mechanical Engineers.

SCHOENBERGER, R. J., and P. W. PURDOM. Classification of incinerator residue. In *Proceedings, 1968 National Incinerator Conference,* New York, May 5–8, 1968. Submitted for presentation and publication. American Society of Mechanical Engineers.

## Systems Analysis for Shipborne Municipal Incineration

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**Grant No. UI 00557–03**
**Fiscal Year: 1967**
**Support: $108,677**
**Project Initiated: March 1, 1965**

OBJECTIVES: To investigate the problem of economic disposal of solid wastes in densely populated coastal areas using shipborne incinerators. To determine the ability of the offshore atmosphere to absorb gaseous pollutants, the effects of incinerator residue dumping on the marine ecosystems and optimization of refuse collection, storage and ship scheduling, using the Boston area as a prototype model.

APPROACH: The scientific and technical aspects of ocean burning of municipal solid wastes and the disposal of the residues at sea are to be examined. Ocean currents and other ecological factors affecting ash movement will be studied to estimate the influence of disposal on marine life. This includes the investigation of bouyancy characteristics of incinerator ash and methods of discharging this ash to prevent floating residues. Studies are also being conducted to determine methods of stabilizing untreated wastes for limited dockside storage periods. Systems analysis and computers will be used to optimize collection networks oriented toward waterfront collection routes. These studies are designed to define the costs, operating characteristics, ecological and environmental health implications, and the proper sphere of operation of incinerator ships.

Preliminary cost analysis indicates that ship incineration is likely to be no more expensive than equivalent land-based incinerators located in the core areas of the city, or sanitary landfills 20 to 40 miles from the collection sites. Toxicity tests with winter flounder and other marine life showed no mortality induced over a 96-hour period at 15 weight percent waste concentration, provided aerobic conditions were present.

## Pyrolysis of Solid Municipal Wastes

**Mr. Donald A. Hoffman**
**Office of Utilities Department**
**City of San Diego, California 92041**

**Grant No. UI 00555–03**
**Fiscal Year: 1967**
**Support: $25,494**
**Project Initiated: June 1, 1965**

OBJECTIVES: To investigate the feasibility of pyrolysis as an economic method of decreasing the volume of solid municipal wastes, the production of useful by-products and the optimum conditions

for operation of the process.

APPROACH: Solid waste characterization studies will be initially made to form the basis of pilot plant charge materials. The municipal solid wastes will be pyrolyzed at various temperatures and the resulting solid, liquid and gas products collected and analyzed.

Solid wastes deposited in San Diego's fills were surveyed for quantity and constitution and a 'Typical San Diego Refuse' was determined. "Typical" samples have been pyrolyzed at temperatures of 900° F, 1,200° F, 1,500° F and 1,700° F using a sample bulk density of 5.44 lb per $ft^3$. Products consist of gases, liquid pyroligneous acids (some 70–80% water) and a more or less contaminated charcoal. Gases have been found to be hydrogen, methane, carbon monoxide, carbon dioxide, ethane and ethylene. The residual charcoal has been found to have a mean thermal value varying from 10,660 Btu per lb to 12,700 Btu per lb. This approximates the Btu content of a semi-anthracite coal.

The pyroligneous acids produced are a complex mixture of organic compounds. Identification of the various components is being performed by gas chromotography and IR spectrophotometry. Methanol, ethanol, isobutanol, N-pentanol, tert. pentanol, 1, 3-propanediol, 1-hexanol and acetic acid have been qualitatively determined. Development of analytical techniques is continuing.

The effects of increased bulk densities upon the products are now being studied at the pyrolyzing temperatures previously cited.

PUBLICATIONS

HOFFMAN, D. A. Burns refuse without a flame. *The American City*, 82(2):102–104, Feb. 1967.

## Continuous Incineration of Municipal Refuse

**Mr. Elmer R. Kaiser**
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**New York University**
**Bronx, New York 10453**

**Grant No. UI 00523–03**
**Fiscal Year: 1968**
**Support: $44,637**
**Project Initiated: September 1, 1965**

OBJECTIVES: To conduct a comprehensive research program on a newly developed, modern municipal incinerator of the continuous-feed type, which incorporates rocking-grate stokers and cyclone dust collectors.

APPROACH: This study is being conducted at the Oceanside Refuse Disposal Plant completed in October 1964, by the town of Hempstead, Nassau County, Long Island, New York. Using this incinerator, the following investigations will be made: determination of the composition of refuse, grate residue, fly ash, refractory slag deposits, waste water pollutants, and gaseous exhausts necessary for a material balance; determination of values of heat release, heat transfer, and refractory furnace temperature necessary for a heat balance, and combustion process factors; and determination of control equipment efficiencies.

Detailed analyses have been obtained for 4 large lots of incinerator input and 2 residue lots. A system was designed for balancing, monitoring and automating underfire airflow for a continuous incinerator. Incinerator modifications have solved a wall-slag buildup problem.

PUBLICATIONS

KAISER, E. R. A new incinerator control meter is needed. In *Proceedings, 1966 National Incinerator Conference*, New York, May 1–4, 1966. American Society of Mechanical Engineers. p. 176.

KAISER, E. R. Composition and combustion of refuse. In *Incineration of Solid Wastes; Proceedings, MECAR Symposium*, New York, Mar. 21, 1967. Metropolitan Engineers Council on Air Resources. p. 1.

## Partial Oxidation of Solid Organic Wastes

**Dr. William W. Shuster**
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**Rensselaer Polytechnic Institute**
**Troy, New York 12181**

**Grant No. UI 00552–02**
**Fiscal Year: 1967**
**Support: $21,234**
**Project Initiated: May 1, 1966**

OBJECTIVES: To investigate the possibility of converting organic solid refuse into useful products through a mechanism of partial combustion using limited quantities of oxygen in a fluidized bed.

APPROACH: A readily available, homogeneous organic material will initially be evaluated. The material will be finely shredded and heated in a tubular reactor with various gas mixtures under batch operation. Combustion products are to be condensed, separated and identified. The research effort is directed at developing a disposal process for organic solid wastes and at developing a process for product recovery that will be economically attractive.

The heated tubular reactor and necessary appurtenances have been designed, fabricated and made operative. Several waste materials which are high in organic content and which are fairly homogeneous, are currently being evaluated as sources of useful products through a process of partial combustion. Such waste materials include finely divided paper, and dried sewage sludge from a sewage treatment plant. The finely divided material is reacted in a packed or fluidized bed with various quantities of air, and the products produced are collected in a series of traps for identification and evaluation. Operating variables such as air–solid ratios, temperature and moisture content are now being studied.

Results to date have indicated the presence of low boiling hydrocarbons, alcohols, organic acids, ketones and other potentially interesting components in the product stream. Other materials remain to be identified.

## Fate of Insecticides in Composted Agricultural Wastes

**Mr. Walter W. Rose**
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**National Canners Association**
**Berkeley, California 94710**

**Grant No. UI 00553–02**
**Fiscal Year: 1967**
**Support: $16,471**
**Project Initiated: May 1, 1966**

OBJECTIVES: To determine the fate of insecticides in composting agricultural wastes by isolation, separation, and identification of residues of the original insecticide and its major transformation products.

APPROACH: Insecticides from three main classes will be incorporated singly or as realistic mixtures in representative wastes before composting. The microorganism responsible for the degradation of each insecticide is to be determined by pure culture isolation and metabolic studies in media containing graduated levels of insecticides. Performance of degrading organisms during composting will be evaluated to ascertain their suitability for technical application. The effectiveness of microbial degradation of insecticides during composting will be evaluated for both continuous and batch operation. Insecticides to be used in this study are DDT, dieldrin, parathion, Diazinon®, zineb, and carbaryl [Sevin®].

Batch and continuous bin type compost experiments were initiated with cannery wastes and rice hulls treated with insecticides. Fresh waste was again added to the batch type experiements after the compost process had gone through a complete cycle. Fresh waste was added to the thermophilic

bins 3 times a week to maintain high temperatures. Active composting proceeded for 4 months followed by 6 months of curing.

The data indicates a rapid decline in the concentration of diazinon and parathion by either compost method. Thermophilic composting reduced the concentration of the insecticides faster than batch type composting. At the end of 120 days, residue levels of both insecticides are almost nondetectable. Breakdown products of diazinon include oxodiazinon and sulphotepp. Breakdown products of parathion are amino parathion, *p*-aminophenol, and *p*-nitrophenol.

DDT is not significantly degraded by either compost method although there is a slow gradual decline under thermophilic conditions. DDE, a normal conversion product, was not detected. Dieldrin is degraded faster in the batch process than in the thermophilic experiment. In the case of dieldrin degradation, microbial utilization appears to be more important than the effect of heat. The batch type process provides more favorable and varied microbial conditions than thermophilic composting. Aldrin, an expected conversion product from dieldrin, was not detected.

PUBLICATIONS

ROSE, W. W., W. A. MERCER, A. M. KATSUYAMA, S. ROSEID, V. Y. PORTER, J. T. YAMADA, J. A. HESP, and J. MARANO. Fate of insecticides in composted agricultural wastes. *Compost Science*. Submitted for publication.

## Comprehensive Studies of Solid Waste Management

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**Sanitary Engineering Research Laboratory**
**University of California–Richmond Field Station**
**Berkeley, California 94804**

**Grant No. UI 00547–02**
**Fiscal Year: 1967**
**Support: $249,585**
**Project Initiated: June 1, 1966**

OBJECTIVES: To develop solutions to problems in all aspects of solid waste management through a research program. This program will combine the competence of specialists in the wide variety of disciplines involved in planning, financing, and administering a community, with the competence of engineers and environmental health specialists.
APPROACH: Nine closely coordinated teams are to be responsible for research in four major areas, namely: operations research, planning and economics, public health, and technology. The research is to proceed within the framework of an overall solid wastes generation and evaluation model. The model involves constitutent submodels which interrelate land use, technology, economics, population, transport, etc., in solid waste generation. In carrying out the research plan the operations research team will develop the overall model from the current conceptual stage to the mathematical stage. The planning and economics team will relate land use to the nature and volume of the refuse materials to be handled. The public health team will evaluate the relationship between solid waste management procedures and health dangers to the public; they will advise the other research teams on the possible public health implications of their alternate proposals for waste management. The collective research of the five teams concerned with technology will be along the following lines: improvement of existing technology (incineration and composting); adaptation of technology to a wider spectrum of waste materials (anaerobic digestion); and application of known processes to develop new techniques (wet oxidation and biofractionation).

This program has generated comprehensive information on many facets of solid wastes and their relationship to, and effect on, the environment.

PUBLICATIONS

UNIVERSITY OF CALIFORNIA. *Comprehensive studies of solid wastes management; first annual report*. SERL Report No. 67–7. Berkeley, Calif., Sanitary Engineering Research Laboratory, University of California, May 1967.

GOLUEKE, C. G., and P. H. MCGAUGHEY. Future alternatives to incineration and their air pollution potential. In *Proceedings, Third National Conference on Air Pollution*, Washington, D.C., Dec. 12–14, 1966, National Center for Air Pollution Control, Public Health Service. U.S. Government Printing Office, 1967. p. 296.

## Nitrogen Cycle Ecology of Solid Waste Composting

**Dr. David T. Knuth**
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**Battelle Memorial Institute**
**Columbus, Ohio 43201**

**Grant No. UI 00548–02**
**Fiscal Year: 1967**
**Support: $23,340**
**Project Initiated: June 1, 1966**

OBJECTIVES: To invstigate the biochemistry and microbiology of the nitrogen cycle during the composting process for treatment of solid municipal wastes. To determine environmental conditions favorable to nitrogen conservation thus making compost better suited to agricultural uses.
APPROACH: The presence of nitrogen cycle microorganisms and their nitrogeneous products will be ascertained in normal compost prepared in the laboratory. The extent to which nitrogen is lost and converted to forms unavailable to the microorganisms which decompose waste will be the basis for the selection of useful environmental modifications. Attainment of these objectives is expected to effect greater waste utilization and nitrogen economy during composting.

A laboratory compost fermentor has been developed which facilitates data acquisition through precise control of the environment. Extensive BOD reduction has occurred over a 20-day composting period and large quantities of organic nitrogen are converted to ammonium compounds and ammonia gas. The occurrence of nitrification during composting is indicated even at thermophilic temperatures.

## Hospital Solid Waste Disposal in Community Facilities

**Prof. Richard G. Bond**
**School of Public Health**
**University of Minnesota**
**Minneapolis, Minnesota 55455**

**Grant No. UI 00549–02**
**Fiscal Year: 1967**
**Support: $28,344**
**Project Initiated: June 1, 1966**

OBJECTIVES: To study the treatment, or destruction, of wastes within the hospital, the disposal of hospital wastes outside the hospital and the community acceptance and disposal of hospital wastes.
APPROACH: In the early phases of the research, investigations will be made at 2 hospitals to establish procedures, followed by waste handling studies at 5 hospitals. Three hospitals are to be studied in large cities. One hospital will be studied in a suburban community where the waste collection is less well developed and where the hospitals are of a different design and operation. The fifth hospital is in a more rural location. After survey techniques are further developed from the experience at these 5 hospitals, 25 hospitals throughout the United States will be selected for similar investigation. Experience obtained from this enlarged study will then be applied to investigations at approximately one-hundred hospitals.

Extensive data do not now exist for evaluating hospital solid wastes. Perhaps the single most important contribution of such data will be the strengthening of existing hospital programs having to do with formulation of design criteria and operative standards.

Over 250 literature references on hospital solid wastes have been abstracted and coded. Survey procedures have been developed and used in 21 hospital surveys. Solid waste measurement and classification methods have been developed, resulting in quantitative and qualitative data acquisition.

## Engineering Properties of Farm Wastes

Dr. E. Paul Taiganides
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Ohio State University Research Foundation
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Grant No. UI 00550–02
Fiscal Year: 1967
Support: $8,981
Project Initiated: June 1, 1966

OBJECTIVES: To develop techniques for measuring and evaluating some of the engineering properties of farm wastes and to determine the effects of changes in feed and environmental parameters on the physical, chemical, and biological properties of farm animal wastes. To define the properties of animal wastes in terms independent of specific handling systems in order to increase the usefulness of animal wastes properties in design.

APPROACH: Data on manure properties will be correlated with such production parameters as mean live weights, feed intake and daily protein intake. Attempts will be made to develop a method of theoretically estimating the quantities and composition of manures from animals reared in total confinement. In these studies, computers will be used to investigate the effect of such parameters as temperature, ventilation rates and humidity, etc., on waste production. Odor production and other nuisances associated with farm waste disposal will be studied.

The study will attempt to show means of waste disposal which have low labor requirements, reduce nuisance conditions, and improve sanitation. Because of the geographic position of Ohio, results of this study should reflect not only production conditions and practice of the central area of the country, but also climatic, urban, and sociological conditions of the region.

## Biological Methane Formation

Dr. Marvin P. Bryant
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Grant No. UI 00693–02
Fiscal Year: 1967
Support: $48,539
Project Initiated: June 1, 1966

OBJECTIVES: To obtain fundamental ecological, nutritional, and biochemical information from mixed and pure culture studies that can be applied to a general understanding of the process of methane formation from organic matter in important natural systems.

APPROACH: The quantitatively significant bacteria, in important natural sites of methane formation, will be enumerated, isolated, and characterized. Studies will be made of habitats in which the anaerobic decomposition of plant food and of organic wastes lead to methane formation. Characterization of isolated methane bacteria will include nutritional studies to establish the relationship of the nutrient requirements of the organisms to the chemical composition of the natural habitat. Methane bacteria, especially those of quantitative significance will be studied biochemically to compare the mechanism of methane formation from various organic substrates, hydrogen, and carbon dioxide.

In addition, the biochemistry of methane formation in *Methanobacillus omelianskii* will be investigated. Other aspects of the biochemistry of methane bacteria will be studied.

It was shown that the organism, *Methanobacillus omelianskii,* previously believed to be the organism responsible for production of methane

from ethanol and carbon dioxide in nature, is actually a symbiotic association of two species. One oxidizes alcohols with production of hydrogen and the other utilizes hydrogen in reduction of $CO_2$ to methane. When an enrichment of ethanol utilizing organisms was made from anaerobic sewage sludge, a similar association of two species was again shown. The methanogenic organism was similar to the methanogenic organism isolated from *M. omelianskii* but the organism responsible for oxidation of ethanol differed from that isolated from *M. omelianskii* in that it was capable of utilizing the hydrogen produced in reduction of sulfate to sulfide. The latter organism is tentatively identified as a species of the genus *Desulfovibrio*. Electron microscopic studies of fine structure indicate that the methanogenic organism from *M. omelianskii* is similar to *Methanobacterium formicicum* but it is not capable of fermenting formate. Studies of cell-free extracts of the methanogenic bacterium isolated from *M. omelianskii* show that they produce methane using reactions similar to those previously shown for *M. omelianskii* except that ethanol is not oxidized. Large-scale techniques for culturing pure strains of methanogenic bacteria using hydrogen as energy source have been developed.

PUBLICATIONS

BRYANT, M. P., E. A. WOLIN, M. J. WOLIN, and R. S. WOLFE. *Methanobacillus omelianskii*, a symbiotic association of two species of bacteria. *Archiv für Mikrobiologie*, 59(1–3):20, Aug. 1967.

## Cellulose Degradation in Composting

**Dr. John S. Jeris**
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**Grant No. UI 00508–02**
**Fiscal Year: 1968**
**Support: $28,572**
**Project Initiated: August 1, 1966**

OBJECTIVES: To investigate and determine environmental conditions required for accelerated cellulose degradation by microorganisms using composting procedures. To translate the results into engineering information so that urban refuse may be treated more economically using the compost process.

APPROACH: Laboratory studies are to begin by setting up a series of compost units charged with defined mixtures ranging from paper to material resembling municipal refuse. The charged material is to receive pure and mixed cultures of microorganisms selected through established procedures and other sources. The bench studies are designed to maximize cellulose degradation under appropriate physical and chemical environmental conditions. The biological and biochemical mechanisms of cellulose breakdown will be investigated. Cellulose and degradation products are to be assayed so that a measure of the system's efficiency and operational mechanisms are obtained.

It is planned to conduct large-scale studies using the laboratory developed conditions for accelerated cellulose degradation in compost. This venture will be directed at determining the most efficient and economical procedures of cellulose degradation in commercial operations.

The research project has succeeded in harvesting biota capable of rapid cellulose degradation using as the microbe source cattle rumen, soil, decaying wood, grass clippings and composting matter. A standardized cellulose assay procedure was adopted from TAPPI and modified to suit compost conditions. Laboratory size compost units have been designed and constructed. Operating characteristics are undergoing evaluation.

## Dynamic Evaluation Procedure; Refuse Handling System

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**Grant No. UI 00513–02**
**Fiscal Year: 1968**
**Support: $28,421**
**Project Initiated: September 1, 1966**

OBJECTIVES: To detail a descriptive simulation model of a solid waste management system in a cooperative study with the City of Atlanta, Georgia. To evaluate the effects of changes made in the system as a result of the study.

APPROACH: The perspective used in this study is called industrial dynamics (J. W. Forrester [1]), which grows out of four lines of earlier development: information-feedback theory, automatized military tactical decision-making, experimental design of complex systems by use of models, and digital computers for low-cost computation. This concept may be used to treat the interactions between the flows of information, money, orders, materials, personnel, and capital equipment in an industrial system.

This study will utilize the solid wastes system of the City of Atlanta for the purpose of data collection. Using this data, the research is to design a model to portray systems behavior, provide a procedure for the evaluation of various proposals as potential system improvements from a standpoint of economy and efficiency, provide insight into the basic nature of the variables inherent in a solid waste handling system, and possibly disclose new important variables not previously understood.

The system being studied has been abstracted into equation form based upon detailed flow diagrams.

[1] FORRESTER, J. W. *Industrial dynamics.* Cambridge, M.I.T. Press, 1961. 464 p.

## Livestock Waste Management and Sanitation

**Dr. Donald L. Day**
**Department of Agriultural Engineering**
**University of Illinois**
**Urbana, Illinois 61801**

**Grant No. UI 00514–02**
**Fisal Year: 1968**
**Support: $30,806**
**Project Initiated: September 1, 1966**

OBJECTIVES: To attempt to refine knowledge of the physical, chemical, and biological properties of livestock waste and to develop methods of waste treatment/management. The project is principally concerned with swine waste management but other livestock and poultry will be investigated to a limited extent.

APPROACH: Primarily a field study will be conducted on the university swine farm equipped with liquid waste facilities; a Pasveer ditch, a series of lagoons, and sandbed filters. The buildings housing the hogs have slotted floors and mechanical means for circulating and removing the manure from beneath the animals.

The studies will consider aspects of the experimental chemical treatment of liquid manure to suppress objectionable gases and odors, and the aerobic treatment plant in a production building. In the chemical treatment study, the type and amount of treating materials needed, the yield and fertilizer value of the solids collected, and the management procedures for removing and utilizing these solids will be determined. In the biological study, the oxygenation and power requirements of a circulating rotor aerator will be investigated. Related investigations will include: inoculum requirements for starting the aerobic process and developing the required bacterial flora, speed of rotor and depth into the wastes, depth of wastes, quantity and fertilizer character-

istics of excess sludge, quality of effluent, and gas production from the plant.

The field laboratory setup has shown that a bacterial inoculum is not required to start the biox process. Severe foaming, poor sludge settling characteristics, brief period of giving off ammonia, and incomplete treatment are some of the problems encountered. Swine waste can be sufficiently odorless, however, with adequate oxygen content. The surplus sludge can be spread as a slurry or irrigated without objectionable odor, if the disposal is made before the sludge has a chance to become anaerobic.

### Publications


Day, D. L. Current status of the oxidation ditch; summary of United States and European research. Presented at, Tenth National Pork Industry Conference, Lincoln, Nebraska, November 9, 1967.

Jones, D. D., B. A. Jones, Jr., and D. L. Day. Aerobic digestion of cattle wastes. Presented at ASAE Meeting, Detroit, Michigan, December 12–15, 1967.


## Pollution of Subsurface Water by Sanitary Landfill


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**Drexel Institute of Technology**
**Philadelphia, Pennsylvania 19104**



**Grant No. UI 00516–02**
**Fiscal Year: 1968**
**Support: $69,414**
**Project Initiated: September 1, 1966**


Objectives: To provide means for predicting the quantitative movement of contaminants in underground water from present and proposed sanitary landfills. To appraise design methods and remedial procedures for reducing, to within specified limits, any undesirable contaminant movement that the study may disclose. To develop hydrologic criteria for evaluating site suitability for sanitary landfill.

Approach: A prototype landfill located in extensive schist formations in part of populous southeastern Pennsylvania has been selected for study. This site is to be studied to clarify the hydraulics of pollution movement in sanitary landfills. In this work, the geometry and associated geological materials, along with their hydraulic properties, will be determined from borings and cores.

The second portion of the study will consist of the development of suitable criteria for the design of sanitary landfill operations and prediction of their performance. This phase will use collected data and will involve a mathematical model and solution by digital computer. An important objective is to develop a contaminant transport prediction model to determine the production of pollutants in landfills, their movement out of the fills, and their movement through, or absorption in, both the saturated and unsaturated zones.

The sanitary landfill site described above has been selected. The geological and hydrological studies are underway. The degradation of the landfill and the production and exportation of pollutants are being studied with the aid of wells, thermisters, radioactive probes and analyses of the landfill's gases and liquids.

### Publications


Begg, B. A. *Sanitary landfill; a bibliography*. Series I, No. 2. Philadelphia, Drexel Institute of Technology, January 1967.

Remson, I., A. A. Fungaroli, and A. W. Lawrence. Water movement in an unsaturated sanitary landfill. In *Proceedings, American Society of Civil Engineers, Journal of the Sanitary Engineering Division*. (In press.)

## The Mode of Action of Pectin Enzymes

Dr. James D. MacMillan
Department of Biochemistry and Microbiology
Rutgers—The State University
New Brunswick, New Jersey 08903

Grant No. UI 00529–02
Fiscal Year: 1968
Support: $21,116
Project Initiated: September 1, 1966

OBJECTIVES: To describe and compare the mode of action of various plant and microbial pectinesterases. To determine if pectin is completely or partially esterfied when originally formed by the plant.

APPROACH: The study will involve specific tests to determine if esterases act in a random or in a linear manner with respect to the polygalactutonide chain. If the enzyme operates linearly as suspected, the direction of the action will be determined in terms of the reducing end of the pectin molecule. Pectinesterase from tomatoes will be investigated, in addition to studies to compare the mode of action of pectinesterases from various plant and microbial sources. As a long-term goal, the structure of naturally occurring pectins will be examined relative to using pectic enzymes as analytical tools.

Initial efforts have been directed at isolating enzymes and evaluating their activity.

## Pipe Transport of Domestic Solid Wastes

Dr. Iraj Zandi
Department of Civil Engineering
University of Pennsylvania
Philadelphia, Pennsylvania 19104

Grant No. UI 00541–02
Fiscal Year: 1968
Support: $39,510
Project Initiated: September 1, 1966

OBJECTIVES: To investigate the application of known technology of solids transport in pipes to the collection and removal of domestic solid wastes, as well as economic comparison with truck collection system.

APPROACH: The hydrodynamics of the flow of various combinations and concentrations of solid waste slurries in different pipe sizes will be examined. The technical aspects of both pneumatic and slurry flow of solid waste will be studied. The stochastic processes governing the generation of solid wastes will be evaluated and their implications for the design of the pipe system studied. An economic evaluation of domestic solid waste services will be made and analytical economic decision models for solid waste systems constructed. Thus, meaningful comparisons of pipe systems and conventional systems can be made.

Major equipment used in this study includes 80-foot loops of pipes of varying diameters, equipped to ascertain flow rates, pressure losses, and density. The experimental setup has been designed, constructed and placed in operation. Studies with varied solid wastes concentrations are being performed.

Thus far, it has been shown that for a certain type of community (Center City of Philadelphia) the collection and removal of solid waste is both technologically feasible and economically attractive.

## Chemical Transformation of Solid Wastes

Dr. Virgil H. Freed
Department of Agricultural Chemistry
Oregon State University
Corvallis, Oregon 97331

Grant No. UI 00510–02
Fiscal Year: 1968
Support: $24,268
Project Initiated: October 1, 1966

OBJECTIVES: To study the chemical conversion of solid wastes to products of economic value and the reduction in volume of solid wastes for easier handling.

APPROACH: The two phases of this study are: (1) to classify and identify the chemical nature of the constituents of solid wastes and investigate methods of chemical transformation of these wastes; (2) to follow the development of suitable laboratory procedures and conduct studies on pilot plant operations, engineering problems, and economic aspects. The first phase will consist of a survey of the literature, experimental determination of wastes not covered in the literature, and a limited investigation of composted materials.

Early efforts in the chemical transformation studies are being directed toward simple wastes, such as grass, straw, and wood wastes, which are problems in the Pacific Northwest. Reactions to be studied for chemical transformation of these wastes will include hydrogenation, chlorination, selective oxidation, nitration, and ammoniation. These reactions will be applied to refuse components singly and in combinations.

Preliminary laboratory work has been done on hydrogenation, destructive distillation, solvent extraction and classification of varied solid wastes materials.

## Effects of Garbage Compost on Soil Processes

Dr. Charles C. Hortenstine
Department of Soils
University of Florida
Gainesville, Florida 32601

Grant No. UI 00521–02
Fiscal Year: 1968
Support: $17,918
Program Initiated: December 1, 1966

OBJECTIVES: To determine toxic or beneficial effects of large amounts of compost on soil. To evaluate compost as a nutrient, a soil amendment, and a source of pollutants in groundwater. To study the long-term effects of large amounts of compost on soil.

APPROACH: Laboratory, greenhouse, and field phases of this study will be conducted concurrently. In the laboratory studies, samples of garbage compost will be examined to determine the microbiological activities, plant nutrient content, organic matter, leaching characteristics, plant material, and various other physical and chemical properties. Optimum moisture and temperature conditions for most rapid decomposition will be utilized. Greenhouse studies will emphasize nutrient availability of the compost as compared with sources such as sewage sludge and mineral fertilizers, compost as a planting or potting medium, and the effetcs of compost on soil structure. In a similar manner, field studies will be conducted throughout Florida on the major soil types with garbage compost as a source of plant nutrient for agronomic and horticultural crops. An attempt will also be made to determine the maximum amount of garbage compost that can safely be applied to a particular soil type. The economic aspects will be important considerations in all these studies.

Extensive greenhouse and laboratory studies of chemical and microbiological factors are underway.

## Poultry Manure Disposal by Plow Furrow Cover

Dr. B. R. Wilson
Bureau of Conservation and Environmental Science. Rutgers—The State University
New Brunswick, New Jersey 08903

Grant No. UI 00528–02
Fiscal Year: 1968
Support: $55,765
Project Initiated: December 1, 1966

OBJECTIVES: To investigate and evaluate the frequency of application, amounts and length of time that poultry manure can be applied to soils by plow-furrow-cover methods without undesirable pollution to groundwater and soils. To develop equipment and techniques for this disposal. To determine the physical, chemical and biological changes occurring in the soil.

APPROACH: Soil respiration studies will be conducted in laboratory and field phases using several local soil types. In the laboratory phase, the ability of the soil to decompose repeated increments of waste will be investigated, as will be the factors which prevent a soil from operating indefinitely as a disposal medium. Carbon dioxide evolution will be used to measure decomposition.

The field studies will be conducted at the University Reseach Center (Adelphia, New Jersey) and at commercial poultry farms. Plots for manure applications of the plow-furrow-cover studies will contain a 4 x 4-ft test strip for percolation studies. In these test strips, lysimeters will be used to monitor the travel of contaminants from the wastes applied to the soil.

## Disposal of Dairy Cattle Wastes by Aerobic Digestion

Dr. Alvin C. Dale
Department of Agricultural Engineering
Purdue University Research Foundation
Lafayette, Indiana 47907

Grant No. UI 00512–01
Fiscal Year: 1967
Support: $56,572
Project Initiated: January 1, 1967

OBJECTIVES: To develop a complete aerobic digestion system for the disposal of dairy cattle wastes. Some of the specific objectives will be to determine the physical, chemical, and biological (biodegradable) properties to show whether preliminary separation of the undigested materials is necessary for aerobic digestion, and to relate the composition of the animal rations, loading rates, temperatures, and oxidation characteristics of the digester to the treatability of the wastes.

APPROACH: Initially, laboratory studies will be conducted and will consist of a series of factorial experiments designed as waste characterization and treatability tests. These will include tank and chamber studies on the particle size effect on decomposition rate, the relationship of animal ration and antibiotics to different temperatures, effects of temperature on aerobic decomposition, and determination of the need of an inoculum for initiating biological degradation. The field phase will be based on the findings of the laboratory phase.

For field studies, it is proposed to design and install a prototype dairy cattle waste treatment system of digestion chambers. Another possibility is the installation of a Pasveer ditch beneath a free-stall barn with a slotted floor. Consideration will also be given to the disposal of the sludge and effluent from the aerobic digestion chambers.

## Microbiology and Acid Production in Sanitary Landfills

**Prof. Jerry C. Burchinal**
**Department of Civil Engineering**
**West Virginia University**
**Morgantown, West Virginia 26506**

**Grant No. UI 00520–01**
**Fiscal Year: 1967**
**Support: $30,505**
**Project Initiated: January 1, 1967**

OBJECTIVES: To determine the effect of nitrogen, phosphorous, and potassium on the decomposition rate of municipal refuse and the succession of microorganisms during decomposition. The occurrence and order of appearance of organic acids will oe determined, and attempts will be made to identify species of microorganisms responsible for formation of organic acids.

APPROACH: Fresh household refuse will be placed in simulated landfills under controlled laboratory conditions. For this, cylinders up to 3 feet in diameter and 16 feet deep are to be used, with the smaller cylinders insulated to decrease the dissipitation of heat. Plastic boxes are also being used as moisture and gas control can be easily accomplished. Chemical analyses and microbial isolations will be made of the solid waste before it is put into the simulated landfills, and later, similar examinations will be made at intervals during the refuse decomposing process.

In another study, to be made during the decomposition of the refuse, an attempt will be made to correlate different organic acids indicative of decomposition to the bacteria which produce the acids, and to establish initial sources of the acids. Correlation of these studies will be made with gas production, quality, quantity, and volume produced per unit of refuse.

## Using Wastes Formed in Vegetable and Cheese Production

**Dr. Amihud Kramer**
**Department of Horticulture**
**University of Maryland**
**College Park, Maryland 20740**

**Grant No. UI 00536–01**
**Fiscal Year: 1967**
**Support: $52,404**
**Project Initiated: January 1, 1967**

OBJECTIVES: To investigate the possibility of utilizing the millions of tons of raw food materials ordinarily disposed of by the food processing and packaging industries. Studies will be conducted on tomato wastes, cottage cheese whey, and other vegetable and dairy wastes to determine their use as new foods, feeds, or additives to food.

APPROACH: Wastes from tomato harvesting, processing, and canning are to be evaluated by chemical, biological, nutritional techniques. Cottage cheese whey will be investigated to find techniques which can produce economical and palatable additives for human consumption.

Preliminary investigations indicate that lactic fermentation can be induced if the tomato waste is chopped and compressed, or if the silage is inoculated with appropriate microorganisms, or enriched with carbohydrates. Feeding studies with ruminants and poultry are underway on such ensiled samples.

Chemical-nutritional analyses of the tomato waste indicate a relatively rich potential source of proteins, pectins, and tomatine. Studies are underway to develop efficient extraction procedures for these components, determination of their nutritional efficiency, and the cholesterol precipitating effectiveness of tomatine.

Preliminary studies with whey indicate that the major problem in utilization of whey in food manufacture is protein instability, which can be overcome by short-time, high temperature heating. Whey so treated is now being utilized in the preparation of low fat milk solids, sherbets, milk-like drinks, wine, and beer, using up to 50 percent whey in the formulations.

### PUBLICATIONS

BEN-GERA, I. and A. KRAMER. Utilization of food industry wastes. In *Advances in food research*. Vol. 17. New York, Academic Press, 1968. (*In press.*)

## Optimal Policies for Solid Waste Collection

Dr. Cornelius W. Kruse
Department of Environmental Health
The Johns Hopkins University
Baltimore, Maryland 21205

Grant No. UI 00539–01
Fiscal Year: 1967
Support: $31,577
Project Initiated: January 1, 1967

OBJECTIVES: To study the feasibility and economics of establishing transfer points in waste collections systems of large cities. To devise, through a computer-oriented systems analysis study, more efficient use of manpower and equipment.

APPROACH: This study will develop information concerning the characteristics of optimal policies for use in urban decisions by engineers and city councils. A mathematical simulation model based on data available from the cities of Baltimore and Tulsa, and from Los Angeles County, will be made to investigate the location and spacing of transfer stations. Such problems as crew size, frequency of collection, vehicle routing, and type of equipment will be analyzed.

The study has prepared and programmed three mathematical models of FORTRAN IV for use in digital computers. These models simulate the operations of solid waste collection systems in urban residential areas using compacter trucks. Proposed policy changes in a system can be evaluated by model use rather than by changes in actual field operations.

The system variables which can be controlled in some or all of the models are: density of households per acre, haul distances from neighborhoods to disposal site, truck crew, crew size, collection frequency, pay scales, overtime policy, amortization policy, season, use or nonuse of a transfer station, size of transfer station trailers, use or nonuse of transfer station compaction apparatus, haul distances from transfer stations to disposal site, and use or nonuse of queues at transfer stations.

The relative efficiencies of the 2 systems being compared are measured in dollars per ton-costs. A comparison of costs of residential triweekly collection versus biweekly collection can be made. For a particular urban tract with the controllable variables defined, the model will generate the number of collection trucks needed for servicing the area and will assign the trucks by number and by days to areas within the tract.

The combinations of variables which make the use of a transfer station economically desirable are investigated.

## Citric Acid from Citrus Wastes by Fermentation

Dr. Sterling K. Long
Citrus Agricultural Experiment Station
University of Florida
Lake Alfred, Florida 33850

Grant No. UI 00540–01
Fiscal Year: 1967
Support: $25,523
Project Initiated: January 1, 1967

OBJECTIVES: To develop a procedure for converting the waste products of citrus processing plants and citrus molasses into useful products such as citric acid.

APPROACH: Selected canning plant waste waters of high biochemical oxygen demand (BOD) content will be used to dilute citrus molasses to the optimum sugar concentration for citric acid fermentation. Tap water will be used for the dilutions in preliminary studies. These studies will determine the conditions and additives required to make the substrate suitable for production of citric acid by strains of *Aspergillus niger*.

Three different sizes of fermentors are planned for these studies. Fernbach Shake Flasks (0.3 liter) will be used to determine the optimum con-

centration of molasses, determine possible effects of interfering ions, and determine optimum environmental conditions for citric acid production in shake cultures. In a 13.5-liter fermentor, the effects of aeration, stirring, pH, and temperature will be studied. For the final phases, results from the first two studies will be scaled-up for pilot plant experiments with a 100-liter fermentor.

## Identification of Odors in Feedlot Operations

**Dr. Edward A. Schuck**
**Statewide Air Pollution Research Center**
**University of California**
**Riverside, California 92502**

**Grant No. UI 00531–01**
**Fiscal Year: 1967**
**Support: $33,623**
**Project Initiated: February 1, 1967**

OBJECTIVES: To identify the odors associated with confinement livestock operations. To provide the analytical means not only for assessing the magnitude and possible effect of the odor on the community but also for assessing the effectiveness of modifying feedlot practices for odor reduction.

APPROACH: This investigation will involve gas chromatographic analysis of air samples collected in and near feedlots. The chromatographic detectors used will largely be of the flame ionization type. After identifying the classes of compounds involved in odors, the individual members of that class can be separated and identified. It is anticipated that prepatory gas chromatography will be used in order to concentrate usable amounts of each individual compound. These concentrated samples will be used for identification by infrared spectrophotometry, organoleptic detection and other techniques.

Subsequent routine sampling at feedlot locations under a variety of conditions will establish the variations in total concentration and ratios between specific odor causing compounds. The results of this phase of the investigation will determine the feasibility of designing a field type odor detector.

## Noncombustive Disposal of Solid Agricultural Wastes

**Dr. Ellis F. Darley**
**Statewide Air Pollution Research Center**
**University of California**
**Riverside, California 92502**

**Grant No. UI 00535–01**
**Fiscal Year: 1967**
**Support: $64,117**
**Project Initiated: February 1, 1967**

OBJECTIVES: To investigate the feasibility of shredding solid agricultural wastes and incorporating them into the soil. To investigate the resulting effects on various plant diseases and insects and on soil properties.

APPROACH: Mechanical shredding operations representing major California fruit and field crops will be carried out at several demonstration plots. Studies will be made of the time and costs of these operations and of the effect on soil physics and nutrition level. In addition, 4 biological studies will be carried out. The first is to determine if adding wood chips to the soil will increase the inoculum potential of a non-soil-inhabiting root rot fungus. The second is to determine the effect on survival and infectivity of certain plant pathogens by adding shredded infected material to the soil. The third is to determine the development of a soil inhabiting fungus pathogen in soils containing shredded plant material. The fourth will study the survival and development of a plant insect pest in soils containing shredded plant material. Consideration will be made of the effects of climate, differences in plant species, and the rate of decay of shredded material and their *in situ* effect on soil properties.

## Conservation of Resources in Municipal Waste

Dr. Dana G. Sturkie
Agronomy and Soils Department
Auburn University
Auburn, Alabama 36830

Grant No. UI 00511–01
Fiscal Year: 1967
Support: $110,290
Project Initiated: April 1, 1967

OBJECTIVES: To determine the value of processed garbage as compared with peat, sawdust, or other mulches for the establishment of grasses, annual plant beds, woody plants, plants propagated by cuttings, plants in greenhouse containers, and cut crops; and to determine the biological properties of a mixture of composted municipal waste and soil.

APPROACH: Several plots will be selected to simulate golf greens, highway median strips, highway backslopes and fills, strip mine and borrow areas. The relative effects of processed garbage, sawdust and peat are to be compared during the establishment of a grass cover using several diffierent types of grasses. The effect of the inclusion of processed garbage in a hydroseeding operation will be evaluated. The inclusion of processed garbage and activated sludge with peat will be evaluated as a mulching compound. Experiments are to be conducted comparing 2 rates of nitrogen application, for example, 80 and 400 lbs. of nitrogen per acre per year. The sources of nitrogen will be processed garbage and ammonium nitrate. Laboratory research will develop data on the rate and extent of release of nutrients such as nitrogen, phosphorus, sulfur, and carbon dioxide by incubation of mixtures of soil samples and compost in the form of pellets, crums or powder. The simulation of the decomposition of organic pesticides by the addition of compost will be investigated in field plot experiments.

## Degradation of Waste Paper to Protein

Dr. John D. Douros
Chemistry & Chemical Engineering
Denver Research Institute (Colorado Seminary)
Denver, Colorado 80210

Grant No. UI 00565-01
Fiscal Year: 1967
Support: $88,472
Project Initiated: June 1, 1967

OBJECTIVES: To evaluate a fermentation method of converting waste paper to a protein supplement for livestock feed. The specific purpose is to obtain an extremely fast growing hydrocarbon cellulose-digesting organism, having a high chemical or protein score.

APPROACH: The initial effort will include isolation and screening of microbes to find suitable strains for rapid digestion of cellulose in a water medium enriched with hydrocarbons, oxygen, and nitrogen. In phase I, the work will center on the isolation of hydrocarbon-utilizing cellulose-digesting organisms by employing enrichment, sprinkle plate, percolation, and gardening isolation techniques. The organisms will be purified and screened for growth. Determination on cell yield, hydrocarbon utilization, cellulose degradation and amino acid profiles will be carried out on the fermentation products. Phase II will involve the optimization of the fermentation process which yields a certain selected organism. These studies will investigate the following variables: pH, temperature, aeration, $CO_2$ requirements, trace elements, nitrogen sources, stimulators, and the effects of certain fractions of waste paper. A comparison of a batch verses a continuous fermentation will investigate the effects of each on product quality and toxicity. Phase III will initiate the design, construction, and operation of pilot scale processes. The pilot plant will be used for two principal reasons: (a) to accumulate necessary data for design of a large-scale plant; (b) to pro-

duce sufficient protein for animal nutrition studies. Phase IV is the nutritional testing of the protein products. Data will be obtained for both small and large animals.

Approximately 450 hydrocarbon utilizing organisms have been isolated. These isolates are undergoing cellulose degradation and protein score evaluation.

## Photosynthetic Reclamation of Agricultural Solid and Liquid Wastes

**Dr. William J. Oswald**
**Sanitary Engineering Research Laboratory**
**University of California, Richmond Field Station**
**Richmond, California 94720**

**Grant No. UI 00566-01**
**Fiscal Year: 1967**
**Support: $26,631**
**Project Initiated: June 1, 1967**

OBJECTIVES: To reclaim agricultural wastes through a study of the basic characteristics of an integrated anaerobic fermentation and algae growth system for agricultural wastes on a pilot plant scale. To ascertain area and volume requirements per unit weight of waste and weight yields of algae per unit weight of waste.

APPROACH: The general aim is the application of an integrated system involving an anaerobic digestion phase and an algae production phase to the disposal of agricultural wastes, especially animal manures, and to the reclamation of the plant nutrients and water contained in the waste. Information will be obtained concerning operating factors, design, criteria, economics, system characteristics and health aspects. In addition, the recycling aspects involve a study of the energetics of the three system activities (anaerobic decomposition, aerobic decomposition and photosynthesis). The physical plant will involve a digester, algae pond, algae harvesting equipment and the necessary algae processing equipment. Poultry and hog manure will be used as a waste source.

## SECTION III

## Solid Wastes Research Grants

## Awarded Between July 1 and December 31, 1967 (Fiscal Year 1968)

## Thermophilic Aerobic Process for Waste Treatmtent

**Dr. John F. Andrews**
**Environmental Systems Engineering Department**
**Clemson University**
**Clemson, South Carolina 29631**

**Grant No. UI 00559–01**
**Fiscal Year: 1968**
**Support: $31,655**
**Project Initiated: August 1, 1967**

OBJECTIVES: To study the application of a thermophilic aerobic digestion process leading to the treatment of organic wastes, particularly to wastes containing 3 to 5 percent solids, e.g., ground municipal garbage, primary and waste activated sludges. To develop a theoretical mathematical model for the process which will express effluent substrate production as functions of input substrate concentration, detention time and oxygen supply rate.

APPROACH: Continuous flow, complete mixed bench scale reactors and a heterogeneous culture of thermophilic microorganisms will be developed and used to test the theoretical mathematical model. The variables to be studied will include: influent substrate concentration, pH, temperature, detention time, oxygen supply rate and gas recycle rate. The reactors will also be subjected to dynamic analysis. A synthetic substrate will be used to assist data procurement and evaluation on the bench scale to be used. Four complete mixed reactors will be automated and generate a considerable amount of data. The large amount of data will be automatically processed and recorded using a Beckman DESTIR System and an IBM 360 computer. It is anticipated that the aerobic, synthetic substrate, thermophilic system and mathematical model developed will lead to pilot plant scale studies utilizing municipal organic refuse and sewage sludges.



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# SECTION IV

## Active Solid Wastes

## Training Grants

**Dr. P. W. Purdom**
**Environmental Engineering and Science**
**Drexel Institute of Technology**
**Philadelphia, Pennsylvania 19104**

**Grant No. UI 01010–02**
**Fiscal Year: 1968**
**Support: $45,427**
**Program Initiated: July 1, 1966**

PROGRAM: This grant initiated a training program in solid waste disposal at the master's degree level. The program is established as a specialized curriculum within the environmental engineering and science program. The emphasis is on solid wastes disposal with graduates trained in community solid waste management and for administration of State and Federal solid waste programs.

Depending upon the electives selected and prior education, students will be candidates for degrees in environmental engineering, civil engineering, and science. The curriculum will provide courses in environmental health design and operation of collection and disposal systems, as well as in general engineering, planning, administration, and management. Besides the interdisciplinary approach at the Institute, a close working relationship exists between the Institute and State and local governments.

**Dr. Frederick G. Pohland**
**School of Civil Engineering**
**Georgia Institute of Technology**
**Atlanta, Georgia 30332**

**Grant No. UI 01011–02**
**Fiscal Year: 1968**
**Support: $46,607**
**Program Initiated: July 1, 1966**

PROGRAM: This grant started a specialized interdisciplinary training program in solid waste technology at the master's degree level. The program will be administered by an interdisciplinary committee, principally from the School of Civil Engineering (Sanitary) and the School of Industrial Engineering.

The program is oriented toward the education of engineers in the unit processes utilized in disposal, systems analysis, and the optimization of collection systems, as well as the economic and administrative aspects of solid wastes management. Students take a core curriculum in solid wastes technology and related disciplines, and attend seminars and special workshops. Major emphasis is on civil, sanitary, industrial, chemical, and mechanical engineering.

**Prof. Eugene A. Glysson**
**Civil Engineering Department**
**University of Michigan**
**Ann Arbor, Michigan**

**Grant No. UI 01013–02**
**Fiscal Year: 1968**
**Support: $39,855**
**Program Initiated: July 1, 1966**

PROGRAM: This grant supports an expanded teaching program in solid wastes at the master's level. It is an interdisciplinary approach developed around the Civil Engineering Department and involving related fields such as environmental health, urban and regional planning, public administration, and others.

The curriculum emphasizes the environmental engineering aspects of the solid wastes problem. Current courses in the Civil Engineering Department serve as a core of the curriculum for the solid wastes program. The program is designed to train personnel to more effectively apply present knowledge to the solid waste problem, and to develop new knowledge and methods in this field.



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**Dr. Joseph F. Malina, Jr.**
**Civil Engineering Department**
**University of Texas**
**Austin, Texas 78712**

**Grant No. UI 01015–02**
**Fiscal Year: 1968**
**Support: $38,103**
**Program Initiated: July 1, 1966**

PROGRAM: This grant is designed to initiate an instructional and research program in the disposal aspect of solid wastes at the master's level. Training will be offered as a specialty within the existing environmental health engineering program, in cooperation with the Department of Chemical Engineering. Objectives include the training of graduate students, the development of a competent health-related teaching and research training program, and the opportunity for both faculty and students to study new approaches to the disposal of solid wastes.

Students specializing in solid wastes take specific courses amounting to at least half the hours required for the master's degree. Their training is directed toward solving problems of municipal refuse disposal. Research efforts will be directed towards solid waste disposal problems.

**Prof. Thomas deS. Furman**
**Department of Environmental Engineering**
**University of Florida**
**Gainesville, Florida 32601**

**Grant No. UI 01012–01**
**Fiscal Year: 1967**
**Support: $37,632**
**Program Initiated: January 1, 1967**

PROGRAM: Support of this program is designed to begin master's level training that emphasizes solid wastes, in a newly formed Department of Environmental Engineering. The program will provide training of personnel for design and operation of solid waste disposal facilities, as well as research personnel for the development of basic data needed to design effective waste disposal systems.

Students specializing in solid wastes will take specific courses amounting to about half the hours required for the master's degree. As the program develops, a systems analysis approach will be included.

An interdisciplinary, all-university committee will coordinate research and training in solid wastes. Initially this committee will include chemical and environmental engineering, and aspects of botany and soils.

**Dr. James H. Schaub**
**Department of Civil Engineering**
**West Virginia University**
**Morgantown, West Virginia 26506**

**Grant No. UI 01014–01**
**Fiscal Year: 1967**
**Support: $68,358**
**Project Initiated: January 1, 1967**

PROGRAM: Support of this program is designed to expand master's level teaching that emphasizes solid wastes. To enlarge this program, research in broad areas on the economic, and engineering aspects of municipal refuse handling, land reclamation, and related special problems will be encouraged.

Students specializing in solid wastes will take specific core courses amounting to at least half the hours required for the master's degree. Qualified nonengineering graduates may enter the environmental engineering program on an open enrollment plan.

The solid waste training program is mutually supporting with graduate programs in air pollution control engineering and water supply and waste treatment. This interrelationship provides the student with the opportunity to participate in an active, broad-scope environmental engineering program.

The graduate education and research at the university has an interdisciplinary approach. This is shown by an exchange of lectures between specialists in sanitary engineering and preventative medicine, a joint research project on sanitary landfills between the bacteriology and civil engineering departments and a joint laboratory effort between the chemistry and sanitary engineering departments.

**Dr. William W. Shuster**
**Division of Bio-Environmental Engineering**
**Rensselaer Polytechnic Institute**
**Troy, New York 12181**

**Grant No. UI 01009–01**
**Fiscal Year: 1968**
**Support: $35,968**
**Program Initiated: July 1, 1967**

PROGRAM: This new program is designed to provided training in supervision, planning, and administration of solid waste disposal facilities, at the master's level. Emphasis on solid waste includes consideration of collection, transportation systems and disposal. The emphasis is directed to courses enabling a broad understanding of solid wastes and its relation to health problems. The New York State Department of Health is cooperating with the Rensselaer Institute faculty.

The program, originating in the Division of Bio-Environmental Engineering, will include engineering, scientific, and economic aspects. It is strongly supported by an interdisciplinary committee consisting of the departments of biology, chemistry, science, and engineering.

**Dr. Ross E. McKinney**
**Department of Civil Engineering**
**University of Kansas**
**Lawrence, Kansas 66045**

**Grant No. UI 01016–01**
**Fiscal Year: 1968**
**Support: $38,050**
**Program Initiated: July 1, 1967**

PROGRAM: Support of this program is designed to expand master's level and to initiate doctoral level training, emphasizing solid wastes. The program is within the environmental health engineering and environmental health sciences curriculum. Its objective is to educate young engineers in the techniques of solving practical problems of solid wastes through research. The interdisciplinary approach is obtained through the participation of the mechanical, industrial, and chemical engineering departments and other fields such as political science, business administration, and economics.

The master's level graduates will be trained for effective careers in state health departments, Federal agencies, engineering companies and industrial organizations. The doctoral graduates will be oriented towards an academic career involving teaching and research in solid waste problems. Both the M.S. and Ph. D. level program emphasize research as a learning experience.

## Research and Training Program Directors


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